Final Report

Anaerobic Digestion Feasibility Study

for the

Bluestem Solid Waste Agency

and

Iowa Department of Natural Resources

June 2004

R·W·BECK

In conjunction with
Nova Energie GmbH and
Resource Development Association

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EXECUTIVE SUMMARY

Introduction and Purpose of Study

R. W. Beck, Inc. (Beck), in conjunction with subconsultants Resource Development Associates and Nova Energie GmbH, was retained by the Bluestem Solid Waste Agency (Bluestem) to analyze the feasibility of anaerobic digestion (AD) of organic solid wastes in Linn County, Iowa.

Bluestem is part of an integrated solid waste management system that includes the following:

- Pay-as-you throw residential refuse collection coupled with curbside collection of recyclable materials and yard waste;
- Commercial and industrial waste exchange;
- Old corrugated cardboard landfill disposal ban;
- Composting of yard waste and organic sludges;
- Energy recovery for select combustible materials; and
- Landfill disposal of remaining solid waste generated.

The objectives of the study were to answer the following questions posed by Bluestem:

1. Where has AD been effectively used to manage targeted fractions of the solid waste stream?
2. Can AD be effectively used to manage the organic fraction of Bluestem's waste stream?
3. What impact would the incorporation of an AD component have on Bluestem's overall integrated solid waste management system?
4. What cost parameters are associated with the application of AD to the management of targeted fractions of Bluestem's municipal solid waste (MSW)?
5. What are the potential barriers to siting and developing an AD facility to manage a portion of Bluestem's MSW?

This Executive Summary presents an overview of the feasibility study and highlights the key findings. The study consists of ten sections, plus several appendices.

Key Findings

The key findings of the study include the following:

- Anaerobic digestion is being effectively used in several locations throughout Europe to manage the organic fraction of municipal solid waste (OFMSW), yard waste, food wastes, organic industrial wastes, sludges, and manures.
- Two potential sized AD facilities – 69,000 TPY (Large) and 36,000 TPY (Mid-Sized) should be considered for future analysis based on available organic feedstock.
- Capital costs for the Large AD facility are estimated to range from $12.8 to $14.2 million.
- Capital costs for the Mid-Sized facility are estimated to range from $9.0 to $9.4 million.
- The net present value (PV) over a 20-year planning period calculating the PV of the revenues less the PV of the operating and amortized costs results in a positive cash flow for a Large AD facility. This assumes revenues from both electric power and thermal energy sales.
- An average tip fee of $14.43 - $16.73 per ton for the Large AD Facility scenario offers an opportunity for project development with adequate revenues to cover projected expenses over a 20 year planning horizon.
- Development of the Large AD Facility offers the potential to produce a quantity of biogas composed of 65% to 75% methane adequate to generate more than 1 megawatt (MW) of electrical power.
- Development of the Large AD Facility offers nearly a 75% reduction in the total volume of materials with the potential for the reuse of the residual fiber as compost.
- The addition of an AD Facility to Bluestem's integrated solid waste management system provides an increased level of flexibility to manage future changes in the quantities and types of materials received.
- Barriers to siting and developing an AD facility are comparable to siting and developing other solid waste facilities.

Anaerobic Digestion Technology Overview

Methane is emitted from anthropogenic sources such as agriculture (rice fields, animal breeding and fattening), incineration and landfills. AD is a technology that can potentially reduce methane emitted from agricultural waste and landfills. AD not only provides pollution prevention opportunities, but also reduces the volume of waste while producing methane and digestate (i.e., fibrous by-product and water). As the technology continues to mature, AD is becoming a viable method for promoting waste reduction, energy recovery of biomass, and useable by-products.

World-wide, there are now more than 130 large AD plants operating that digest the organic fraction of the municipal solid waste stream (OFMSW) and/or organic industrial wastes (OIW). All but approximately five of these installations are located in Europe. Various AD technologies, including wet and dry digestion processes, are described in detail, illustrated with pictures and diagrams in the report.

Survey of Anaerobic Digestion Facilities

Because there are no commercial-scale AD facilities operating in the U.S. that use MSW or the organic fraction of MSW (OFMSW) as feedstock, an extensive survey was initiated of AD facilities in Europe. Facilities digesting at least 2,500 tons/year of either the OFMSW or Organic Industrial Waste (OIW) as its feedstock, or those feedstocks co-digested with other organic materials, were selected for the survey. More than 60 facility operators or system providers representing AD facilities from ten different European countries were surveyed. A summary of the results is provided in Table ES.1 below.

Table ES.1
Performance Data of AD Plants

Location	Waste Type*	Waste Tons/Year	Ft^3 Digester	Ft^3 Gas Production	Ft^3 Biogas/Ton	Ft^3 Gas/Ft^3 Digester/Day	Lbs./Day/Ft^3 Digester
Aarburg	Yard	12,128	52,973	28,605,150	2,359	1.48	1.25
Baar	Yard	4,410	16,951	13,419,700	3,043	2.17	1.43
Bachenbülach	Yard & Food	9,482	18,364	30,017,750	3,166	4.48	2.83
Baden-Baden	Food & Kitchen	7,166	211,890	51,206,750	7,146	0.66	0.19
Braunschweig	Kitchen	17,640	59,329	60,035,500	3,403	2.77	1.63
Buchen	MSW	110,250	141,260	141,260,000	1,281	2.74	4.28
Geneva	Yard	13,230	35,315	42,378,000	3,203	3.29	2.05
Grindsted**	Biosolids & Food	38,036	98,882	22,954,750	603	0.64	2.11
Holsworthy**	Manure & Food	160,965	282,520	137,728,500	856	1.34	3.12
Karlsruhe	Yard & Kitchen	8,820	47,675	30,935,940	3,507	1.78	1.01
Lemgo	Yard & Kitchen	37,485	90,053	134,197,000	3,580	4.08	2.28
München	Yard & Kitchen	27,563	84,050	52,972,500	1,922	1.73	1.80
Niederuzwil	Yard	11,025	31,784	30,724,050	2,787	2.65	1.90
Otelfingen	Yard	13,781	29,665	38,846,500	2,819	3.59	2.55
Rümlang	Yard & Food	7,718	16,245	28,252,000	3,661	4.76	2.60
Samstagern	Yard & Food	8,489	18,364	28,958,300	3,411	4.32	2.53
Average		30,512	77,207	54,530,774	2,922	2.65	2.10

* When there is more than one type of waste, the higher percentage feedstock is provided first.
** While not a part of the survey, sufficient information was gathered to make consistent comparisons.

As reflected in the data presented in Table ES.1, the average surveyed system treats a waste volume of slightly more than 30,500 tons/year, and has a reactor volume of around 77,000 ft^3. With an average yield of almost 2,900 ft^3/ton of biogas, the average AD system produces slightly more than 6,200 ft^3/hour of biogas.

Given the available information, Beck conducted a multiple regression analysis for the facility survey results. The purpose of this analysis was to attempt to quantify some of the economies of scale typically present when building a large, capital-intensive project such as the potential Bluestem project. The multiple regression analysis indicated that on a cost/ton basis of installed capacity projects with higher installed capacities tend to capture the benefits of economies of scale, and cost less to build on a cost/ton basis than smaller facilities.

To illustrate the economies of scale, the resulting equation from the regression analysis was used to estimate the total installed costs of facilities capable of processing two different size facilities - 36,000 and 69,000 tons per year (per the available feedstock as outlined in Sections 3 and 4 of the report). The total installed costs of the 36,000 tons/year facility were estimated to be approximately $9.0 million, equating to a cost/ton of approximately $251/ton. The total installed costs for a 69,000 tons/year facility were estimated to be approximately $12.8 million, equating to a cost/ton of approximately $186/ton. The results clearly confirm that economies of scale are reflected in the survey results.

Generators of Potential Feedstock

The Beck Project Team, with input from Bluestem staff and the Best Practices Roundtable, developed a written survey to assess the availability of organic materials as feedstock for an AD project in the Bluestem planning area. The specific purpose of the survey was to determine the types of organic wastes generated, quantities generated, present management methods, estimated management costs, and level of interest in utilizing AD from the organic waste generators in the Bluestem area.

Table ES.2 below summarizes the survey responses of the various types and amounts of organic waste generated in the Bluestem area.

Table ES.2
Type and Amount of Organic Waste Generated and Diverted

Type of Waste	Tons Generated	Tons Diverted	Current Diversion Method			
			Tons Composted	Tons Land-Applied	Tons Recycled	Tons Used as a Fuel
Sludges	64,728[1]	64,728	64,728	-	-	-
Other Organic Waste[2]	36,724	36,519	5,696	30,823	-	-
Paper (includes OCC, ONP, Office Paper & Mixed Paper)	1,984	1,678	-	-	1,678	-
Food Waste[3]	44,934	44,144	-	-	16,144	28,000
Yard Waste	362	52	52	-	-	-
Pallets and Other Wood	503	369	-	-	369	-
Fabric	160	104	-	-	104	-
TOTAL:	149,395	147,594	70,476	30,823	18,295	28,000

[1] Per discussions with Bluestem staff, approximately one half of this amount would be available for anaerobic digestion.
[2] Other organic waste includes: Feed; fiber filters; dry starch waste; bathroom towels; filter cake by-product; biomass by-products made of denatured bacterial cell bodies, protein, nitrogen, carbohydrates, phosphorus, copper, zinc, and organic, non-toxic polymers.
[3] Food waste includes waste from manufacturers of food products, as well as cafeteria waste from institutions and industries.

Of the total organic waste generated, the respondents to the survey reported that 147,594 tons or 99% of the organic waste is currently being diverted from disposal (the material is being composted, land-applied, reused, re-manufactured, or used for energy production). However, in several instances, these methods were not considered long term management options.

Co-Products Characterization

The co-products of the AD process are a medium-Btu content biogas and a slurry called digestate. The biogas contains approximately 60%-70% methane and is water saturated. The balance of the biogas mixture is carbon dioxide, and some parts/million (ppm) of hydrogen sulfide. The digestate consists of undigested solids, cell-mass, soluble nutrients, other inert materials, and water.

Based on the survey results reported in Section 3, the potential organic feedstock quantities and qualities available to Bluestem are summarized below.

Table ES.3
"Base Case" Organic AD Feedstocks

	Tons/Year	Tons/Day
Sludges[1]	32,364	89
Other Organic Waste	33,300	91
Food Waste	2,934	8
Yard Waste	362	1
Total	68,960	189

[1] Per discussions with Bluestem, this is the total amount that would be available for AD, approximately one-half of the total amount generated.

Table ES.3 depicts a "base case" scenario for AD feedstock within the Bluestem planning area. Of the total amount of organic waste generated (149,395 tons/year), about 46% (68,960) tons can be considered as potential AD feedstocks.

Potential AD Facility Cost Analysis

To complete the potential AD Facility cost analysis, Beck undertook the following steps:

1. Developed an integrated materials flow and financial model to project energy production, materials flow, facility construction and operation, costs, and anticipated revenues;
2. Reviewed AD facility survey results to estimate per ton installed capital costs;
3. Evaluated per ton installed capital costs to determine economies of scale associated with varying AD facility sizes;
4. Calculated projected capital costs for construction and installation of a Mid-Sized AD Facility and a Large AD Facility;
5. Developed conceptual engineering cost estimates for both Mid-Sized and Large AD Facilities as a comparison to the calculated projected capital costs;
6. Identified the scope of the revenues and expenses associated with an AD Facility;
7. Developed a set of financial pro formas for a twenty-year planning period for both AD Facility scenarios;
8. Conducted sensitivity analyses to identify critical variables; and
9. Characterized the financial results to determine the financial viability of the proposed project.

Utilizing the base assumptions as outlined in the "Expected Case", the projected operating results reflect a self-sustaining project at the Large Facility level with both electric power and thermal energy revenues. As for the Mid-Sized facility, the projected operating results reflect a net loss both with and without thermal revenues.

A summary of the net PV analysis on a per ton basis is provided below in Figures ES.1, ES.2, and ES.3.

Figure ES.1
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Projected 20-Year Profit/ton

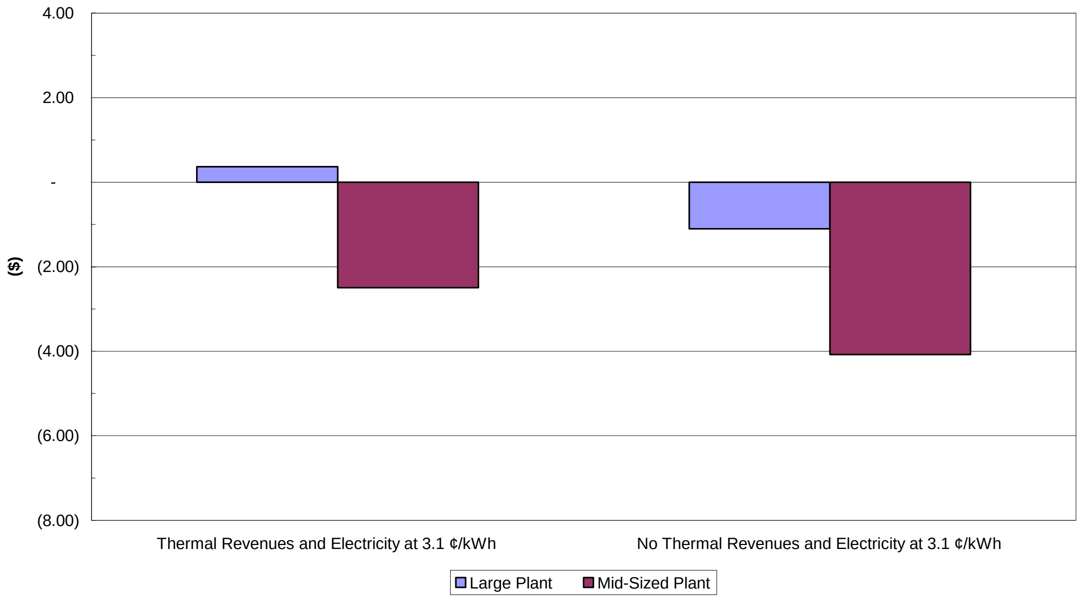


Figure ES.2
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Large AD Facility 20-Year Profit/ton

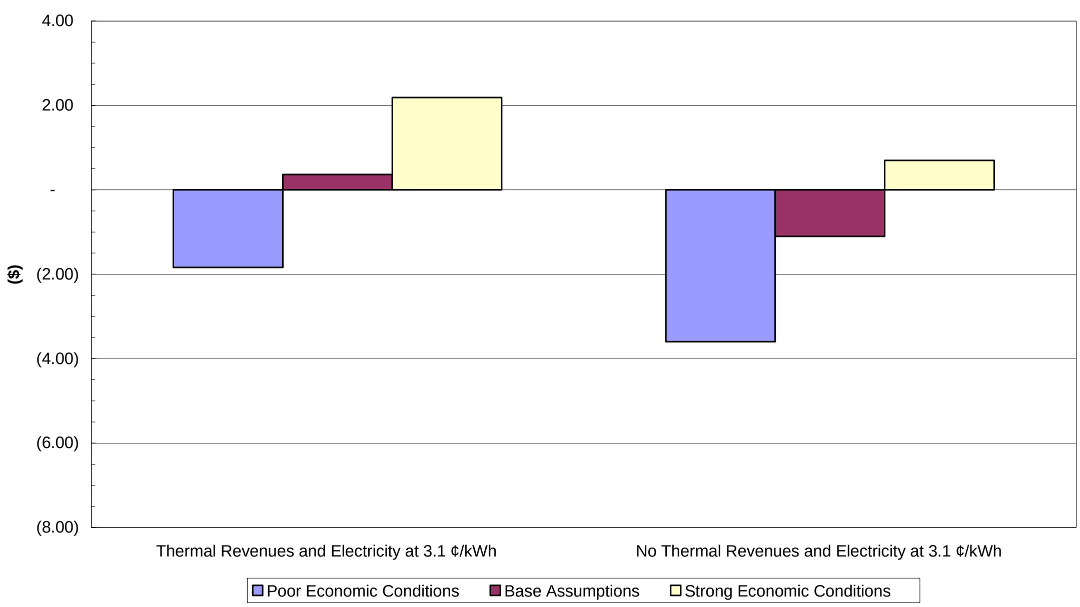
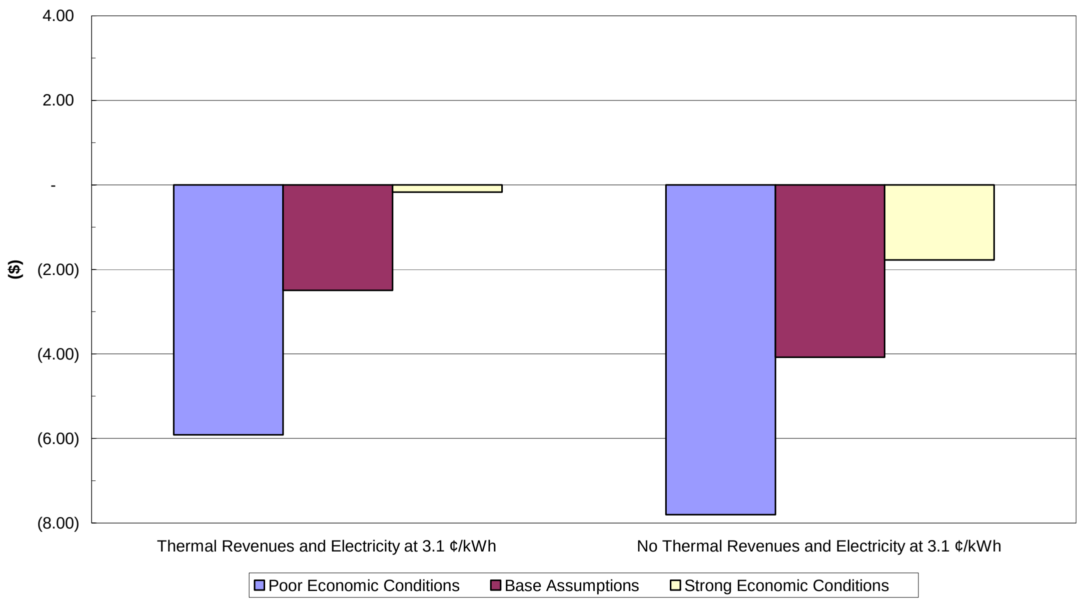


Figure ES.3
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Mid-Sized Facility 20-Year Profit/ton



Because the project is likely to generate revenue through a per ton tip fee charge for materials received, one additional analysis was undertaken. The total revenues for the 20-year planning period were compared to the total annual costs. To generate adequate revenues with the expected case assumptions, a set of tip fees were calculated.

Overall, the average tip fees needed for a revenue-neutral project are characterized in Table ES.4.

Table ES.4
Revenue-Neutral Tip Fee
($/ton)

	Base Case	Mid-Level
With Thermal Energy	$14.43	$18.91
Without Thermal Energy	$16.73	$21.37

The tip fees ultimately selected must be at a level to economically attract the needed waste streams.

Siting and Institutional Issues

The Cedar Rapids Water Pollution Control Facilities (CRWPC) has approximately 30 to 40 acres of open space within its present facility footprint. Per discussions with CRWPC staff, it is the CRWPC's intent to use this area for expansion of its own facilities in the future. However, further discussions with CRWPC concerning the potential use of this area for an AD facility and sponsorship by the CRWPC are recommended.

Per discussions with CRWPC staff, it is estimated that CRWPC uses $5.5 to 6M of power annually. Total power costs represented approximately 15% of total operating costs in the 2003 calendar year. As for natural gas, the CRWPC facilities use biogas from their own treatment processes to displace their own natural gas needs from external sources. Locating an AD facility adjacent to the CRWPC facilities and generating electricity that could be used for CRWPC is an attractive option.

Because AD facilities using MSW as feedstock do not presently operate in Iowa, there is no specific precedent serving either local or state governments surrounding the issue of siting and permitting of this type of solid waste facility. Overall, the uniqueness of an AD Facility will likely require local and state regulators to revisit solid waste facility regulations. Additional legal review of these provisions is recommended prior to initiating the siting and permitting process.

System Impacts Analysis

Adding the AD facility component to the Agency's System to manage the growing targeted waste stream will be beneficial. An AD facility component provides an increased level of flexibility to the Agency's System to promote long term capabilities to address changes in quantities and types of materials received.

The greatest impact on System costs would likely be at the existing composting facility. However, the overall cost impacts of adding this component to the System are anticipated to be minimal, unless alternative facility scenarios are considered that target materials presently being landfilled.

Comparative Life Cycle Analyses of MSW Technologies

For the review of the energy balance, there are two basic outputs (methane and compost) and two basic inputs (electricity and thermal energy). Table ES.5 characterizes the net energy balance.

Table ES.5
Net Energy Balance

	Outputs M BTU/Yr	Inputs M BTU/Yr	Energy Balance (Outputs less Inputs) M BTU/Yr
Methane	87,800		
Soil Conditioner	9,700		
Electricity		4,600	
Thermal Energy		5,500	
Totals	97,500	10,100	87,400

Overall, the analysis reflects AD is a net energy producer. Provided below is a summary of the greenhouse gas (GHG) emissions analysis.

Table ES.6
Anaerobic Digestion
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
Collection	.006	-	-	-	.006
AD Process	.011	-	.15	-	.16
Composting	.0023	-.083	.0001	.0001	-.080
Electricity Production	-.028	-	-.002	-	-.030
Total	.045	-.083	.14	.0001	.056

Overall, the process has an impact on global warming comparable to landfilling with recovery of gas. The negative values represent metric tons of carbon equivalent (MTCE) precluded from being emitted. Table ES.6 provides the overall estimate.

Potential Project Funding Sources

Based on the review of the funding sources outlined in Section 9, the likelihood of federal support for an AD project from existing appropriations is limited. As for the Environmental Protection Agency, both the Innovations Work Group and National Center for Environmental Research are potential funding sources. Additional discussions are recommended with representatives of both programs to determine potential interest in AD projects. For funding directly related to AD facility design, construction, and operation, the Project Team recommends further investigation of the Iowa Department of Natural Resources’ Energy and Waste Management Bureau's Solid Waste Alternatives Program and the Iowa Energy Center's Alternate Energy Revolving Loan Program.

Section 1
ANAEROBIC DIGESTION TECHNOLOGY OVERVIEW

1.1 Overview

Methane is emitted from anthropogenic sources such as agriculture (rice fields, animal breeding and fattening), incineration and landfills. Landfills are estimated to account for 12%-15% of the total greenhouse gas (GHG) emissions on a global basis.

Anaerobic digestion (AD) is a technology that can potentially reduce methane emitted from agricultural waste and landfills. AD not only provides pollution prevention opportunities, but also reduces the volume of waste while producing methane and digestate (i.e., fibrous by-product and water). As the technology continues to mature, AD is becoming a viable method for promoting waste reduction, energy recovery of biomass, and useable by-products.

1.1.1 Source Separation

In many countries, municipal solid waste (MSW) is collected as a mixed stream and is disposed of directly into landfills or in waste-to-energy facilities. In recent years, both source separation and recycling have become more prevalent. As a result, the "clean" organic fractions of MSW (OFMSW) may now be available for biological treatment in some settings.

In many European countries, the source separation of the OFMSW is actively encouraged. This includes separating the putrescible organic fraction, also known as “green waste” or “biowaste”. Source separation sometimes also includes other organic fractions, such as smaller pieces of yard trimmings, non-recyclable papers, and diapers. The residue that remains after source separation is known as "grey waste".

Experience in Europe and the U.S. has shown that comprehensive source separation of organics provides the best quality feedstock for either composting or AD, with a minimum of heavy metal and plastic contamination. Where source separation has been mandated in Europe, the results have been encouraging. The experience of some European communities indicates that 30%-50% percent of the total OFMSW fraction can be successfully collected and managed separately.

The most applicable characteristics of AD feedstock are used when the organic fraction can be collected at the source of generation, (e.g., food processing industries, pulp and paper mills, etc.). In addition to the low degree of contamination, there is a more consistent composition of the waste over time that makes it easier to achieve a steady level of biogas production. This is optimal for conversion into a useful energy by-product.

1.1.2 Centralized Separation

Centralized separation provides the method for obtaining the OFMSW when source separation is not feasible. Centralized separation techniques include mechanical processing, optical processing, and handpicking. Separation is initiated prior to the AD process; however, it is even more efficient to do it after treatment or by combining pre- and post-treatment sorting. The combination of centralized separation and biological treatment (aerobic composting, AD, or both processes in series) is generally called "Mechanical Biological Treatment" (MBT).

The digestible organic fraction obtained from centralized separation is usually more contaminated than source-separated biowaste. Centralized separation particularly affects the heavy metal and plastic content of the digestate co-product. If the digestate derived from mechanical separation does not meet the standards required for its useful application as a soil conditioner, the benefits of AD are derived from only the effective use of the biogas as fuel, from waste volume reduction, and from reducing methane emissions from a landfill site. In some countries this type of lesser-quality digestate is used for landfill cover or for land remediation purposes.

Centralized separation followed by a biological treatment can also be applied to the grey waste residual after source separation. There are approximately 60 systems operating in Europe today that utilize MBT. Sweden, Denmark, The Netherlands, Germany, Switzerland, and Austria are all presently debating the banning of landfilling of organic materials.

1.2 AD Systems Review

1.2.1 Evolution of Digestion Capacity

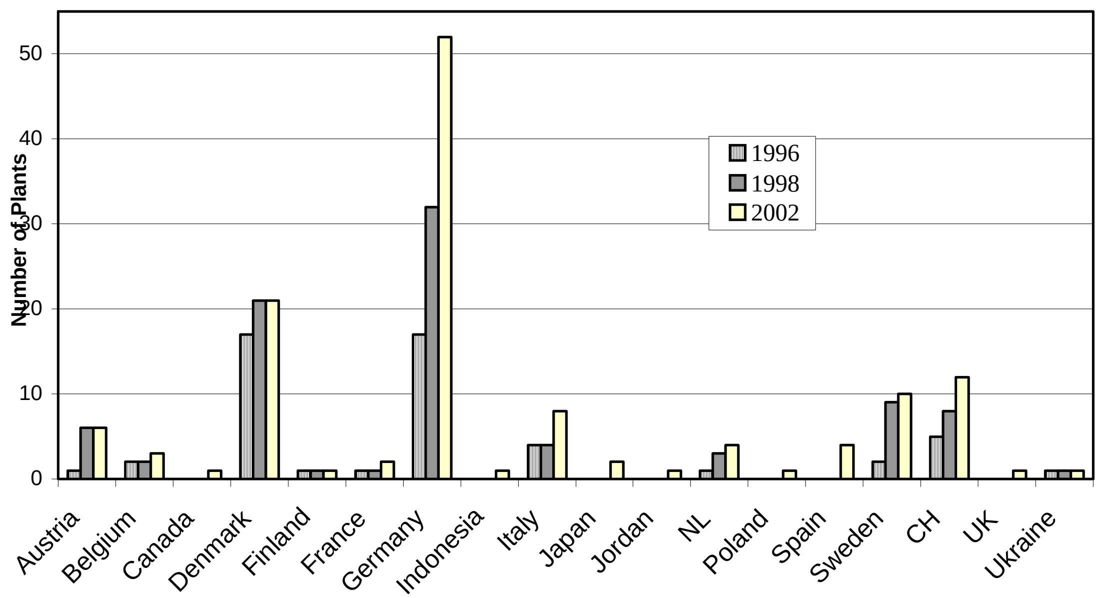
World-wide, there are now more than 130 large AD plants operating, that digest the OFMSW or organic industrial wastes (OIW). All but approximately five of these installations are located in Europe. The total annual installed capacity is around 6.6 million tons. About one fourth of the capacity consists of OFMSW, OIW or sewage sludge, the remainder being mainly manure. Roughly two-thirds (87) of the plants are wet digesters (< 15% total solids or TS concentration), while the remaining facilities systems use a dry digestion process. Provided below is a list of those AD facilities operating in Europe with centralized separation.

Table 1.1
Large MBT Facilities Operating with Digestion

System	Country	City	Type of waste	Tons/Year	Start-Up
BTA/Roediger	Poland	Pulawy	MSW	24,200	2001
BTA	Italien	Villacidro	MSW	38,500	2001
Citec	Finland	Vaasa	MSW, Biowaste	16,500	1994
Citec/Vagron	Holland	Groningen	Grey Waste	253,000	2000
Dranco	Germany	Bassum	Grey Waste	14,850	1997
Dranco	Germany	Kaiserslautern	Grey Waste	22,000	1999
Dranco	Italy	Rome	MSW	44,000	2002
Dranco	Spain	Alicante	MSW	33,000	2002
ISKA	Germany	Buchen	Grey Waste	27,500	2000
Ionics Italbia	Italy	Bellaria	MSW	4,400	1988
Linde	Spain	Barcelona Ecoparc	MSW	165,000	2002
Snamprogetti	Italy	Verona	MSW	55,000	1998
Valorga	Belgium	Mons	MSW	41,250	2001
Valorga	France	Amiens	MSW	93,500	1988
Valorga	France	Varennes-Jarcy	MSW	110,000	2001
Valorga	Italy	Bassano di Grappa	MSW, Biowaste, SS	60,500	2002
Valorga	Spain	Cadiz	MSW	126,500	2001
Valorga	Spain	La Coruña	MSW	156,200	2001
Wehrle Werk	Germany	Kahlenberg	MSW	22,000	2001

The rate of installed capacity of biowaste digestion has increased by an average of 130 thousand tons/year during the 1998-2000 period. The construction of plants per year rose from an average of three (1992-1994) to 15 (1998-2000). As shown in Figure 1.1, most of these facilities have been developed in Germany (52) followed by Denmark (21), Switzerland (12) and Sweden (10). The total treatment capacity for OFMSW (without sewage sludge or manure) has evolved over the last ten years from 134 thousand tons/year to roughly 1.2 million tons/year in Europe, which corresponds to an increase in capacity of 900%.

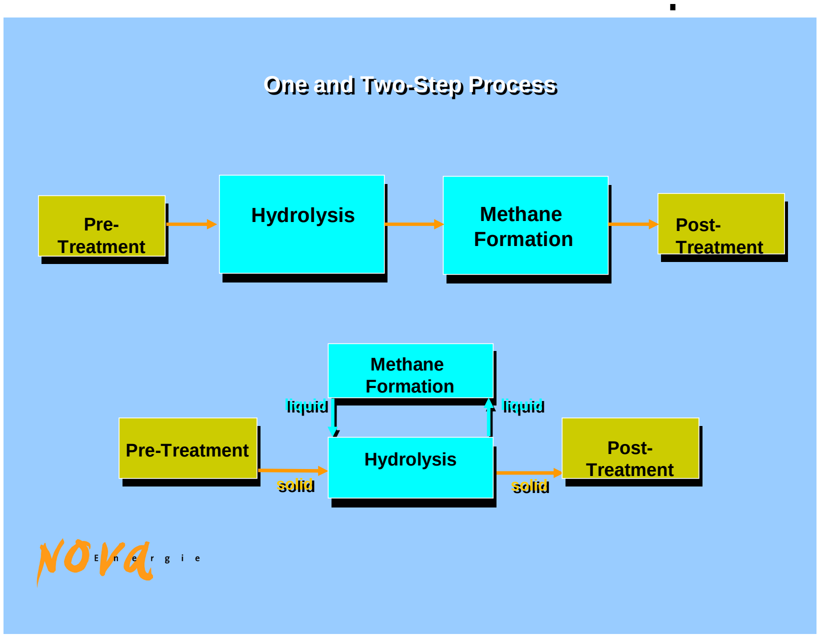
FIGURE 1.1: Development of Biogas Plants



1.3 Anaerobic Digestion Technologies

A wide variety of engineered systems have been specifically developed for the rapid "invessel" digestion of the OFMSW and other types of organic wastes. Each has its own special benefits and constraints. A general overview of the basic principles is given in Figure 1.2, which can be applied to either wet or dry fermentation techniques. Provided below is a characterization of the various wet and dry AD methods.

Figure 1.2 AD Process



1.3.1 Wet Single-Step

In a single step AD process, OFMSW is slurried with a large proportion of process water to provide a dilute (10%-15% TS) feedstock that can be fed to a complete mix tank digester, often called a continuously stirred tank reactor (CSTR). When used for OFMSW digestion alone, dilution water from the wet digestate is recycled for feedstock preparation to avoid generating an excessive volume of diluted digestate for disposal. Typical examples are the Citec plants (also called Wabio system), Babcock Borsic Power or the Haase plants.

Of course, there are limits to the recycling of the dilution water. All kinds of non-degradable organic and inorganic substances are accumulating in the make-up water. Hence, a sink, (i.e., a polishing step) has to be integrated or occasionally external water has to be added. This is generally the approach for all of the AD processes where water is recycled.

In general, the wet single-step systems are not very well suited for digesting the OFMSW alone. Besides the accumulation of sand and stone sediments in the reactor and a formation of plastic films, a fibrous material has a tendency to form strings that wind around the CSTR’s stirrer.

The wet concept readily lends itself towards co-digesting the OFMSW with more dilute feedstocks such as animal manures or sewage sludge. Approximately 50 of the 90 wet systems in Europe co-digest the OFMSW with manure. Most of them are located in Germany, Sweden and Denmark. Most of the Danish Centralized AD (CAD) systems and Swedish digesters are operated as co-digestion plants with manure as the main substrate.

1.3.2 Wet Multi-Step

There are a few multi-step wet digestion processes where the OFMSW is slurried with water or recycled liquor and fermented by the hydrolytic and fermentative anaerobic bacteria to release volatile fatty acids. These fatty acids are then converted into biogas by a high-rate anaerobic digester. Typical examples include some of the Linde-KCA-Dresden plants or the Schwarting-Uhde system.

The BTA process uses a pulper to disrupt the preliminary chopped waste and to separate the plastics and the inerts. The original BTA process was a classical multi-step system with up to two hydrolysis tanks (biological and chemical hydrolysis) and a high-rate anaerobic filter. Recently, the pulper has replaced the chopper and the mechanical separation unit now generally serves as a wet separator.

The new "Percolation" system combines a two-step, two-phase procedure. In a first step, the waste is aerobically percolated (solid phase) and the recovered organic-rich liquid is anaerobically digested in a second step by a high-rate hybrid-filter (liquid phase).

1.3.3 Dry Continuous

This concept involves a continuously-fed digestion reactor using a feedstock with a total solids (TS) concentration of approximately 25%-40%. Both completely-mixed and plug-flow systems are available. The dry technologies are probably among the best adapted systems and most commonly used technologies for OFMSW (see Table 1.2) and source separated MSW digestion.

Vertical plug-flow systems rely on an external recycle of a large proportion of the outgoing digestate to inoculate the incoming raw feedstock. Because the entire waste in the digester is recycled within two days, recycling also provides a mixing system. A typical example of this approach is the Dranco system.

Horizontal plug-flow systems use equipment with a slow, intermittently rotating stirrer and therefore recycle only a small proportion of the digestate. The most typical example for this type is the Kompogas system.

There is one fully mixed dry system on the market, which is Valorga. Feedstock mixing is done by introducing compressed biogas. In all three cases, the requirement for only minimal water additions makes the overall heat balance favorable for operating at thermophilic digestion temperatures (122°F-131°F).

1.3.4 Dry Sequencing Batch

This approach batch-loads the digester reactor (at least three) with raw feedstock and inoculates it with digestate recovered from the previous cycle. The reactor is sealed and then left to digest naturally. During this closure period, leachate is exchanged between established and new batches to facilitate start up, inoculation (from the last reactor) and removal of volatile materials. At the same time, recirculating the pre-heated leachate serves to maintain a uniform moisture content and heat in the digester. When digestion is complete, the reactor is reopened, unloaded and refilled with a fresh load of raw feedstock.

Pilot units of this process have been operated at a test site in Hamburg-Harburg and at the Kahlenberg landfill. However, no full-scale dry sequencing batch system has yet been built to digest MSW. The operation of the process is labor-intensive.

1.3.5 Dry Multi-Step

A dry multi-stage system is a continuous system. The waste passes through a hydrolysis reactor and is subsequently fed from the first to a second and, finally, to a third AD reactor. Each reactor treats the waste in a specific state of degradation. The reaction rate of a large number of reactors approaches a pure plug-flow system. The ROMopur facility in Switzerland is the only operating example of this method in Europe.

1.3.6 Percolation

The percolation process is a two-step technology. In the first dry step, the OFMSW is aerated in a closed, continuously operated reactor. Hydrolytic bacteria form soluble compounds from the solid organic material, which are washed out by recycled water. In a second step, the dissolved organic compounds are converted into biogas in a high-rate industrial wastewater digester, usually an anaerobic filter. Both the aerobic and the anaerobic reactors are operated in a continuous mode.

1.4 AD Development

After four years of applied research at the University of Illinois, the first full-scale digester with a design capacity of 110 tons/day was built in Pompano Beach, Florida during the early 1980's. The so-called RefCom system operated two wet CSTRs with a volume of 44,100 ft^3 each. Unfortunately, the pre-treatment steps could not fulfill the needs of a wet digestion process. This facility, similar to many of the first AD systems, was built to manage the entire MSW stream.

The first demonstration units for the dry digestion of OFMSW were built in Europe in 1984. Valorga developed a plant in La Buise, France with a capacity of 8800 tons/year. At the same time Dranco built its first pilot unit having a reactor size of 1765 ft^3.

1.4.1 Operating Temperatures

Initially, OFMSW digestion plants were operated at mesophilic temperatures (95°F-100°F). In 1992, Kompogas began developing the first OFMSW digester to operate in the thermophilic temperature range. Since then, thermophilic digestion has become a more commonly used technology. Roughly half of the biowaste digesters today are operated at a higher temperature level. This results in the advantage of faster degradation, greater biogas yields and increased pathogen destruction.

1.4.2 Plant Suppliers

A total of 45 different system providers were identified at the initiation of this project that have each constructed between one and 15 plants capable of digesting the OFMSW. As shown in Table 1.2, Kompogas has built the largest number of plants (15) followed by Krüger (14) and BTA (13). The largest volumes of waste are digested in Krüger plants (950 thousand tons/year) followed by Valorga (835 thousand tons/year) and Farmatic (405 thousand tons/year). Ten companies presently have a 62% market share by number and a 63% market share by volume.

Table 1.2
AD Plant Number and Capacity (10 Major Providers)

System	Type	# Plants	Total Capacity (tons/year)
Krueger	Wet	14	950,400
Valorga	Dry	10	833,250
Linde	Wet & Dry	9	499,400
Farmatic	Wet	4	409,200
BWSC	Wet	3	403,700
BTA	Multi-Step	13	367,400
Kompogas	Dry	15	203,000
Schwarting Uhde	Wet	2	193,600
NIRAS	Wet	5	189,750
Dranco	Dry	9	188,650
Total		84	4,238,350

It is interesting to note that the number of system providers who are still developing AD plants during the past two years has been dramatically decreased. With the increasing volumes of the plants and the tendency for waste management agencies to specify design, build, own and operate (DBOO) facilities, there is a clear market concentration toward larger companies. As a result, some of the smaller providers have sold their AD business units and some of the specialized firms have been bought by larger companies.

1.5 Process Description

1.5.1 Wet Single-Step Processes

In the following section, three newer systems will be described for the wet digestion of MSW either alone or in co-digestion with other substrates:

- Digestion of OFMSW after central separation (Vagron, NL)
- Co-digestion of sewage sludge with source separated OFMSW (Grindsted, DK)
- Co-digestion of manure with source separated OFMSW (Holsworthy, UK)

1.5.1.1 Vagron, The Netherlands (Wabio)

Vagron operates as a combined MSW sorting and fermentation facility. Vagron receives about 250 thousand tons/year of household waste and comparable commercial waste (primarily office, shop and service waste).

The sorting facility at Vagron produces the following by-products:

- A refuse-derived fuel (RDF) generating approximately 10.3 million Btu/ton;
- A paper and plastic fraction generating approximately 15.5 million Btu/ton;
- A low-calorific organic wet fraction (OWF) generating around 4.3 million Btu/ton;
- Three iron fractions (raw iron, tin and fine iron); and
- A non-iron fraction.

In theory, the RDF can be burned in a waste incineration facility. However, the RDF is currently stored at a landfill site because the necessary incineration capacity has not yet been made available. The paper/plastic mixture accounts for 15% of incoming household waste by weight or about 38,500 tons/year. The paper/plastic mixture is pressed into bales and used as fuel by the cement industry or by power and heat generation facilities.

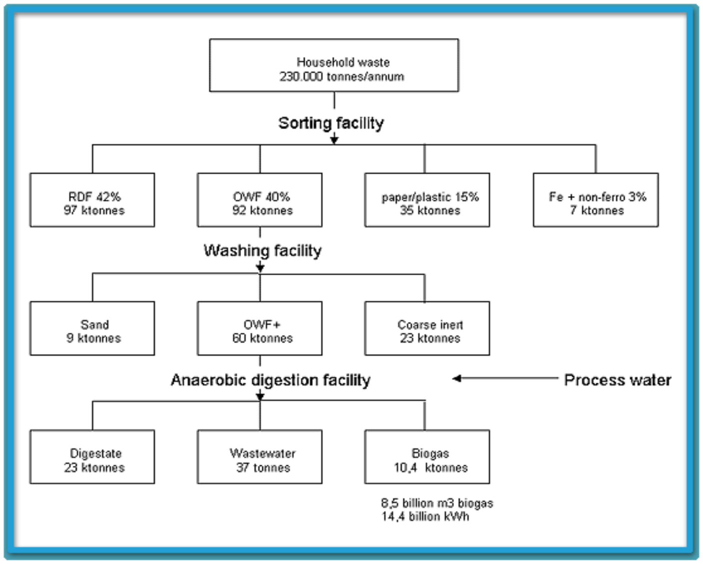
Figure 1.3: Vagron AD Facility

To reduce blockages and wear as much as possible, the inert material and poorly fermentable material must first be removed from the OWF. This is completed in a washing facility consisting of various washing/rotary sieves, upstream separators, a hydro cyclone and a drainage table to drain the separated silt stream. With the addition of water, several steps separate the OWF into three separate streams:

- Washed OWF;
- Sand and inert material (stones, ceramic, glass debris); and
- Unwanted components (plastic, textiles).

The washed OWF is pumped into one of the four mixing tanks, where it is homogenized and brought to the operating temperature of 130°F and around a 12% TS by injecting steam and adding process water from the pressed digestate. From the mixing tanks the OWF is pumped in one of the four digesters of about 97,000 ft^3 each. During the 18 day HRT, the degradation rate of the OWF amounts to about 60% of its initial weight.

Figure 1.4: Vagron Facility Mass Balance



Around 35,300 ft^3/hour of biogas is produced, which is dewatered and stored in a low-pressure biogas balloon with a volume of around 75,000 ft^3. This corresponds to a biogas yield of 1,440 ft^3/ton of raw waste input to the plant.

The residual digestate is dewatered in a press. The digestate is a sanitized and stabilized co-product from the fermentation process that is comparable to compost in terms of structure and composition. It does not, however, meet the specifications required for agricultural use.

The process water is treated with a physical/chemical method to remove floating material, after which it is mostly reused within the washing facility. Only a small portion of the process water is discharged. This discharge water is mixed with waste water from the fermentation facility and directed to the municipal waste water treatment plant (WWTP). The mass balance for the Vargon system is provided above in Figure 1.4.

1.5.1.2 Grindsted, Denmark (Krüger Biosolid System)

In the Danish town of Grindsted, source separated household waste, OIW and sewage sludge are co-digested to supply electricity, heat and fertilizer to the local community. In 2001, the total inputs consisted of 33,000 tons of sewage sludge (dry matter 990 tons), 1,650 tons of organic household waste (dry matter 725 tons) and 3,300 tons of liquid OIW (dry matter 220 tons).

The biogas plant, constructed in 1996, is located adjacent the town’s municipal WWTP. Household organic wastes are collected in paper bags. It is reported that the contamination rate is less than 1%. It is crucial to obtain a clean deglassed product, for the overall process. The plant is designed to handle up to four times more of household waste than it presently does and therefore is presently underutilized.

Figure 1.5: Grindsted Waste Shredder

The biogas plant receives the source separated household organic wastes generated from about 7,000 households. Because the waste is collected in paper bags at the individual households, expensive pre-treatment is avoided at the biogas plant. The bags are unloaded into a receiving silo and subsequently the waste is shredded into pieces that are sized at approximately two inches. Metal parts are removed by a metal separator. The household waste is then mixed with OIW and sewage sludge, and is then pulped for about 15 minutes. The OIW consists of flotation fat from a food processing industry. The feedstock is mixed in a ratio of one part OIW to nine parts sludge or similar. Then, the viscous mixture is pumped through a macerator for fine shredding and a separator for removal of glass and inerts before it is heated to 160°F for one hour in one of two hygienization tanks. Finally, the biomass is pumped into a 100,000 ft^3 reactor and digested at 100°F.

The digestate leaves the digester reactor with about a 2.5% TS concentration. A separator removes any residual materials, mainly plastic, before the digestate is separated by a filter band press. The resulting fiber fraction has a 20%-25% TS content, and the liquid reject fraction is recycled to the municipal WWTP. The fiber is delivered to the farmers free of charge, and is spread on approximately 1,850 acres of farmland.

Figure 1.6: Grindsted AD Facility

About 110 tons/day of feedstock is added, resulting in a daily biogas production of about 63,500 ft^3. This corresponds to a biogas yield of 580 ft^3/ton of raw waste input to the plant. The biogas is used in a combined heat and power (CHP) plant that produces about 250 kW of electricity and 350 kW of heat. Because the CHP engine-generator is designed to run full load, it is possible to have a biogas storage balloon of only 18,000 ft^3 to keep maintenance expenses at a minimum. Annual electricity production amounts to 855 thousand kWh, and the annual thermal energy production is 8.5 billion Btu. The electricity is sold to the public grid, and the thermal energy is used to heat the plant buildings and to heat the feedstock in the hygienization tanks as part of the internal AD process. The facility is depicted in Figure 1.6.

1.5.1.3 Holsworthy, United Kingdom (Farmatic)

The Holsworthy operation is a CAD system that co-digests manures and household waste. It is comparable in design to most of the 20 large-scale CAD operations in Denmark. The manure is collected from 25-30 local farms within a 5 to 10 mile radius. The food waste is collected from food processors in the area southwest of Devon in the United Kingdom (UK).

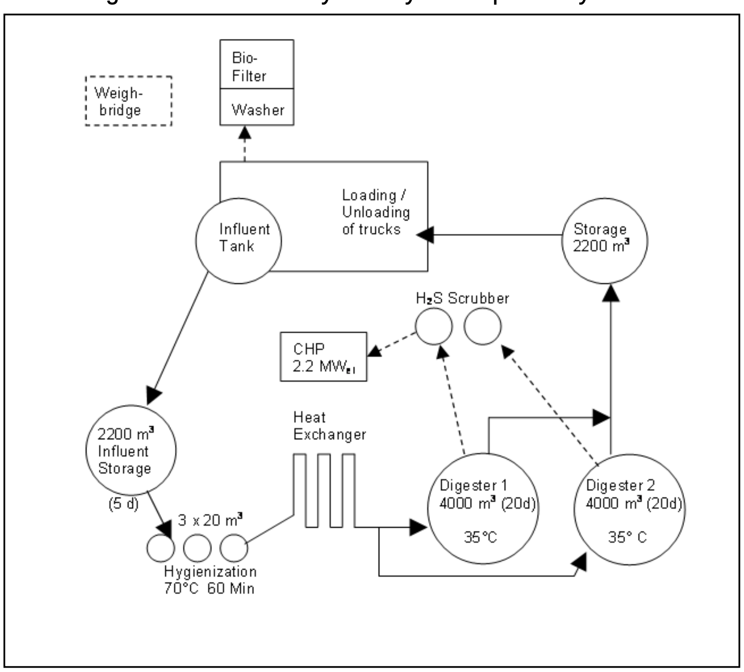
It was originally planned that the plant would be built by Krüger. When Farmatic bought the AD division from Krüger (respectively from Vivendi), they continued the planning work. The plant initiated operation in June of 2002. As of October 2002, the plant was still in start-up phase.

Figure 1.7: Holsworthy AD Facility

During the planning and development of the project, obstacles have included lack of investors and concerns raised related to spread of animal diseases because of the commingling of manures. The facility is depicted in Figure 1.7.

The total annual inputs to the Holsworthy plant are projected to consist of 160,000 tons of food and animal waste. About 440 tons/day of feedstock is added, resulting in a daily biogas production of about 630,000 ft^3. This corresponds to a biogas yield of 1,425 ft^3/ton of waste input to the plant. The layout of the facility is provided below in Figure 1.8.

Figure 1.8: Holsworthy Facility Conceptual Layout



The biogas will be used to generate electricity and recover heat from two engines with a total power capacity of approximately 2.1 MW. Expected power production is around 14.4 million kWh/year. Recovered heat is expected to be sold for use in a new district heating system.

Including engineering design and consulting fees, the total 1996 investment for the entire plant was £5.0 million (around $8.0 million). Interestingly, Farmatic participated with 50% of the invest funds required for project capitalization.

1.5.2 Wet Two-Step Processes

The market penetration of the wet two-step process technology is limited. Specifically, the advantage of having a faster degradation during the digestion step is usually not enough to compensate for the higher capital cost of anaerobic hydrolization as a first step. In practice, the hydrolization step is often more like a storage with uncontrolled liquefaction. However, one preferred application of the wet digestion process is the co-digestion of the OFMSW and sewage sludge or manure. There are two suppliers of this type of technology: BTA (MAT) and Linde-KCA-Dresden.

1.5.2.1 Kirchstockach, Germany (BTA)

The BTA process was developed to transform the OFMSW from households, commercial, and agricultural waste into biogas and compost. The system consists of three major processes: mechanical wet pre-treatment in a pulper for size reduction, anaerobic hydrolization, and biomethanation.

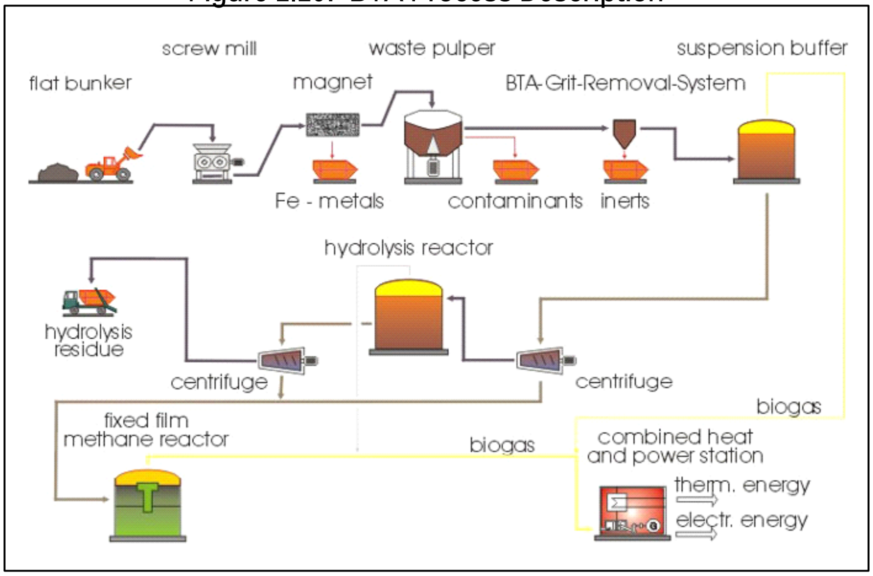
Figure 1.9: The Kirchstockach AD Facility

After passing over a scale, the delivered waste is unloaded into a flat bunker in a receiving hall. It is then fed by a front loader into two screw mills that coarsely chop the organic material, which is fed into two dissolution tanks (pulpers).

The core element of the BTA process is the hydro-pulper where the preshredded feedstock is diluted to 8%- 10% TS (maximum 12% TS) and chopped. Contaminants such as plastics, textiles, stones, and metals are separated by gravity. Sand and stones sink and can be later removed from the bottom; plastic materials tend to float to the surface and are removed by a rake.

An essential component of the process is the grit removal system, which separates the residual fine matter such as sand, little stones, and glass splinters by passing the pulp through a hydrocyclone that is designed to fight the abrasion these materials can cause. The mechanical treatment is followed by a sanitation step (30 minutes at 160°F) before the pulp is processed by the biological degradation step.

Figure 1.10: BTA Process Description



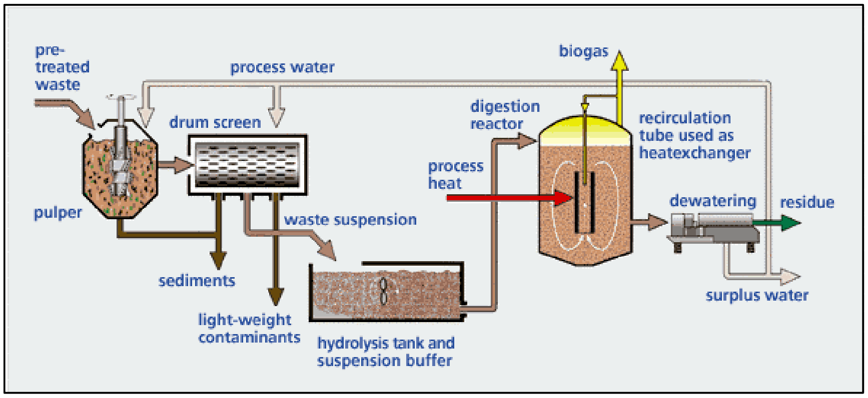
The biological degradation step is divided into a hydrolysis step and a biomethanation step that occurs in a fixed film reactor. Before the hydrolysis step, the suspended materials are dewatered and separated into liquid and solid factions. The liquid contains a high volume of previously dissolved organics, and is pumped directly into the AD reactor. The dewatered solids are re-mixed with process water and fed into the hydrolysis reactor to dissolve the remaining organic solids. After 2-4 days the hydrolyzed suspension is dewatered and the hydrolysis-liquid is also fed into the AD reactor. The fiber that remains after hydrolysis is a high quality material: it is free of pathogens with a low-salt concentration. Post-digestion composting is generally not needed.

The liquid fraction is treated by a cleaning system that consists of sedimentation steps and a biological nitrification/denitrification step to remove some of the nutrients. Most of the cleaned liquid is reused as process water by the pulpers for the treatment of further waste. A small amount of the liquid is discharged as mechanical-biological pre-cleaned surplus water and is fed into the public sewer for final handling by a municipal WWTP. A process description is provided in Figure 1.10 for reference.

1.5.2.2 Wels, Austria (Linde-KCA-Dresden)

Linde-KCA-Dresden GmbH is a wholly owned subsidiary of Linde AG. Linde's wet digestion system for OFMSW is comparable to the BTA design with the major difference being how the light fraction is separated. The light fraction is separated via a drum screen and not within the pulper.

Figure 1.11: Linde-KCA AD Process Description



Depending on the type of input material, Linde's two-stage wet digestion processes can be run at either thermophilic or mesophilic temperatures. The characteristic feature of the Linde technology is how the digestion reactor is fitted with a gas recirculation system using a centrally located recirculation tube.

The AD plant at Wels is part of the city's integrated recycling park, which includes an incinerator, a combined AD plant and composting unit, a unit for recycling of demolition material, and an industrial waste sorting unit. It is depicted below in Figure 1.12.

Figure 1.12: Wels AD Facility

The OFMSW is collected from an intermediate storage area and it is fed into the pulper/drum screen in a batchmode. The pulper has a volume of around 700 ft^3, with a 13% TS concentration. The mashed waste stream is stored in a buffer tank where it undergoes a first hydrolysis step in a tank having a 4,600 ft^3 volume. From the hydrolysis tank, the waste stream is fed into the AD reactor that is operated at thermophilic temperatures. The AD reactor is sized to have a loading rate of 0.375 lb of volatile solids/ft^3/day. With a 16 day HRT, the AD reactor has an effective volume of 56,500 ft^3.

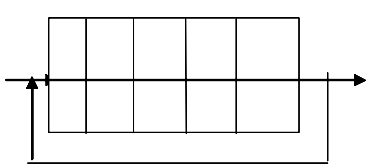
As the facility is only operated 5 days a week, about 66 tons/day of feedstock is added with an average 30% TS concentration. The volatile solids concentration averages 75%-82% of TS. Biogas yields range from 3,100-4,850 ft^3/ton of raw waste input to the plant, with a methane content of 60%-65%. The biogas is used in a boiler that produces about 335 kW of heat. There is a biogas storage balloon having a capacity of 28,200 ft^3. The thermal energy is used to heat the plant buildings and to heat the feedstock in the sanitation tanks.

The digestate is dehydrated and the liquid fraction is recycled for use as process water. Excess water is discharged for processing by an on-site WWTP before it is discharged into the sewer system. The solid fraction undergoes a final composting process together with sewage sludge.

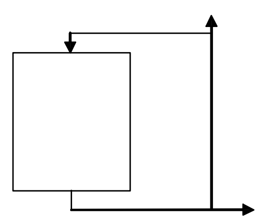
1.5.3 Dry One-Step Processes

There are four major dry one-step processes presently being commercially used that are distinguished from each other by their method of heating (steam injection or heat exchanger), the material flow method (horizontal-flow, vertical down-flow or up-flow), and the mixing method (recycling, radial mixing, transversal mixing, comprehensively mixed by gas injection). However, these dry one-step processes all are operated with 28%-35% TS concentrations. Provided below in Figure 1.13 are conceptual representations of the one-step processes for four different vendors.

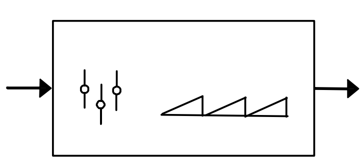
Figure 1.13: One Stage Dry Digesters



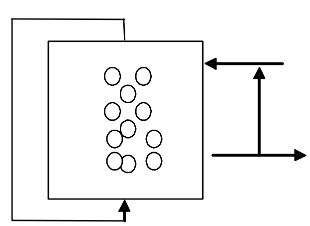
Kompogas
Single-Step Horizontal Plug-Flow



Dranco
Single-Step Vertical Plug-Flow



Linde-KCA
Single-Step Horizontal Flow



Valorga
Single-Step Vertical Gas-Stirred

1.5.3.1 Niederuzwil, Switzerland (Kompogas)

Depending on the size and method of integration of the digester, Kompogas offers either steel or concrete digester reactors. In its original design, Kompogas fully integrated the steel digester reactor into a building. In its second design phase, the AD reactor has been built of concrete and made part of the building. In the newest design (see Figure 1.14), which lowered the cost by a factor of two, the AD reactors are modular units of either concrete (>22,000 tons/year) or of steel (5,500-11,000 tons/year).

The Niederuzwil plant was first constructed with the original design having an indoor steel AD reactor having the capacity to process about 8,800 tons/year. It was then extended by adding a new outdoor steel digester with a capacity of about 5,500 tons/year.

Figure 1.14: Kompogas AD Process

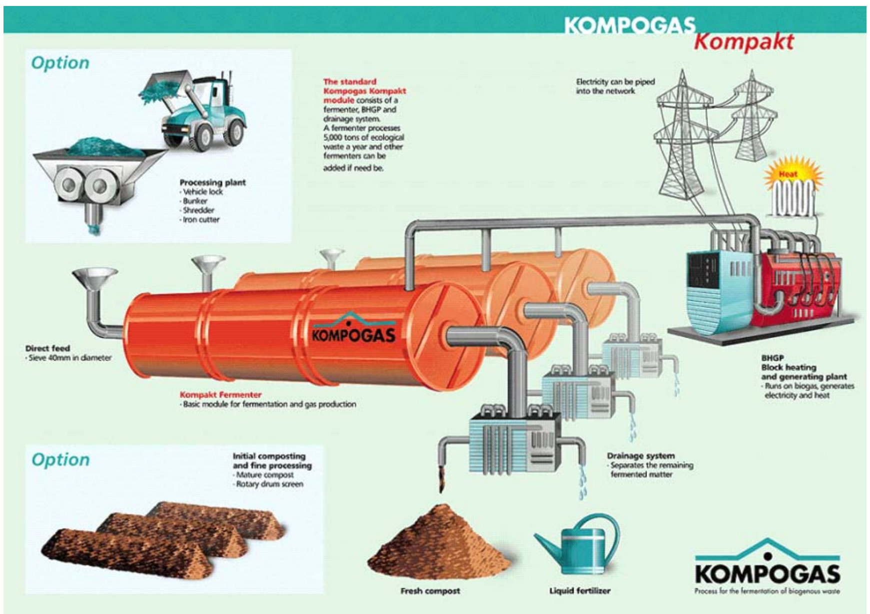


Figure 1.15: Uzwil AD Plant.

In the existing plant, the waste is received in a pit and transported to a shredder having a mesh size of approximately 1.5 inches by a fully automatic crane. The undesirable materials are removed by hand-picking. The upgraded waste is stored in a container that uses a walking floor. This management measure enables Kompogas to be the only provider to offer an AD system that can operate 7 days a week without constant presence of operators. Since the system can function with just two manual checks/day and an emergency alarm system as back-up, this can minimize overall operational costs. In Figure 1.15, the old digester is in the background building and the new modular digester is in the foreground.

Kompogas digesters are operated at 130°F to ensure that the digestate is fully sanitized. The average HRT is 15-18 days. Because of the proper plug-flow operation with a guaranteed HRT, the Kompogas system is the only AD system to have passed sanitation requirements prescribed by German regulation. The digester mixer does not destroy the plug flow characteristics because it moves very slowly - only a partial rotation in intervals. The feedstock is heated in a tubular heat exchanger alongside the digester as depicted in Figure 1.16.

Figure 1.16: Kompogas Heat Exchange

Figure 1.17: Kompogas Separation Press

Part of the digestate is recycled and mixed with the fresh material to assure inoculation. The larger part of the digestate is separated into a liquid fertilizer and a fiber as depicted in Figure 1.17. The fiber can potentially be composted.

1.5.3.2 Lemgo, Germany (Linde-BRV)

The Linde-BRV dry digestion system is similar to the Kompogas system, with a few minimal design differences. For example, some of the reactor heating is done outside the digester with a short heat exchanger, but primarily heating occurs within the digester walls using a heat exchanger.

After solid separation only the liquid fraction is recycled which leads to a lower inoculation rate and, hence, a little longer HRT. As shown in Figure 1.18, the process is not a plug-flow system because feedstock mixing is more pronounced with the transversal paddles and the walking floor.

Figure 1.18: Linde-BRV Process

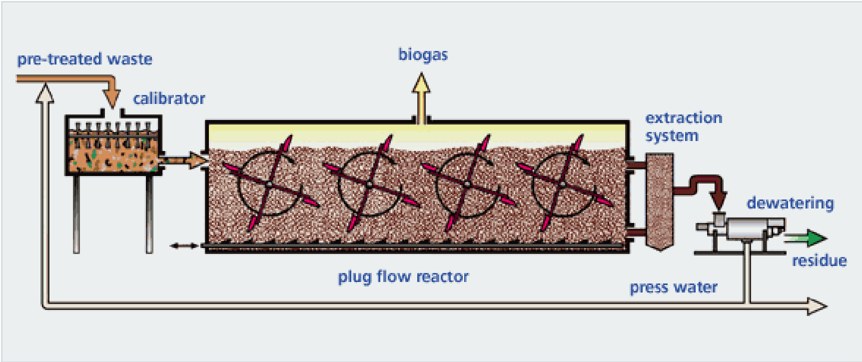


Figure 1.19: Removal Vat

Figure 1.20: Chopper/Calibrator

An innovative part of the design is the batch-wise removal of the feedstock into a recipient reactor under negative pressure and the thermal concentration of the liquid digestate in a vacuum dryer at a temperature of 160°F. The BRV system uses much more equipment than a comparable Kompogas system. Equipment components are depicted above.

In Lemgo, the OFMSW is reduced in size by a screw mill and undergoes a 2 to 4 day period of anaerobic hydrolysis. Before the treated material is fed to the digester, it is chopped by a calibrator into 1.5 inch pieces. After thermophilic digestion with an

HRT of about 21 days, the digestate is separated into a liquid fraction with a 20% TS content and a solid fraction having a >45% TS content. The liquid fraction is recycled to dilute the incoming fresh waste, and to moisten the compost windrows. The excess liquid is concentrated and added to the compost. The fiber is post-composted for 30 days.

1.5.3.3 Geneva, Switzerland (Valorga)

Valorga operates at least 13 AD facilities in Europe as of 2003. The feedstocks include primarily municipal solid waste and biowaste.

The basic layout of the Valorga plants has remained much the same since the mid 1990's. The digester reactor is built in concrete and intermittently mixed by adding compressed biogas. Figure 1.21 below depicts the Geneva AD Facility. Most of the Valorga AD systems are operated at mesophilic temperatures as opposed to the more commonly used thermophilic.

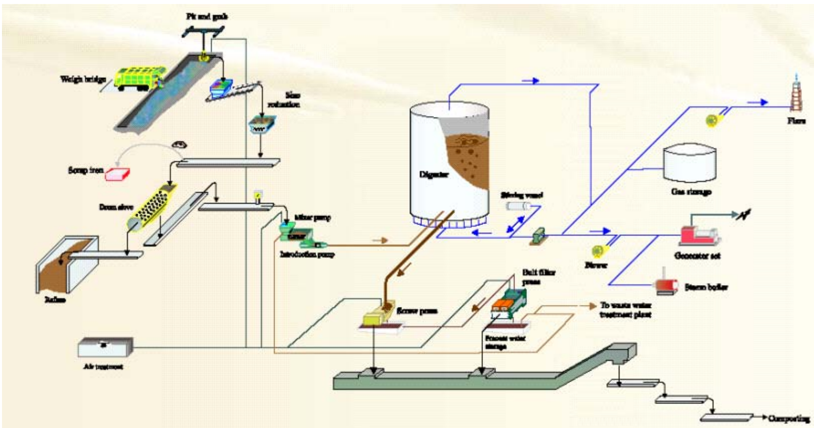
Due to the operating characteristics in Geneva, the methane content of the biogas is lower when compared to some other processes. The average methane content of the biogas is about 55% when the system is operated at mesophilic temperatures. The process has slightly higher methane content when operated under thermophilic conditions.

Figure 1.21: Geneva AD Facility

At Geneva, only source separated organic waste is digested. The plant is designed for 11,000 tons/year, with peak loads equivalent to 13,200 tons/year. After milling and mechanical separation (mesh size 2.5 inches), the waste is fed into the digester using a Putzmeister double screw mixing pump. At the same time, a part of the digested material is recycled in order to inoculate the fresh material. The dry matter is adjusted with recycled water to a TS concentration of approximately 30%.

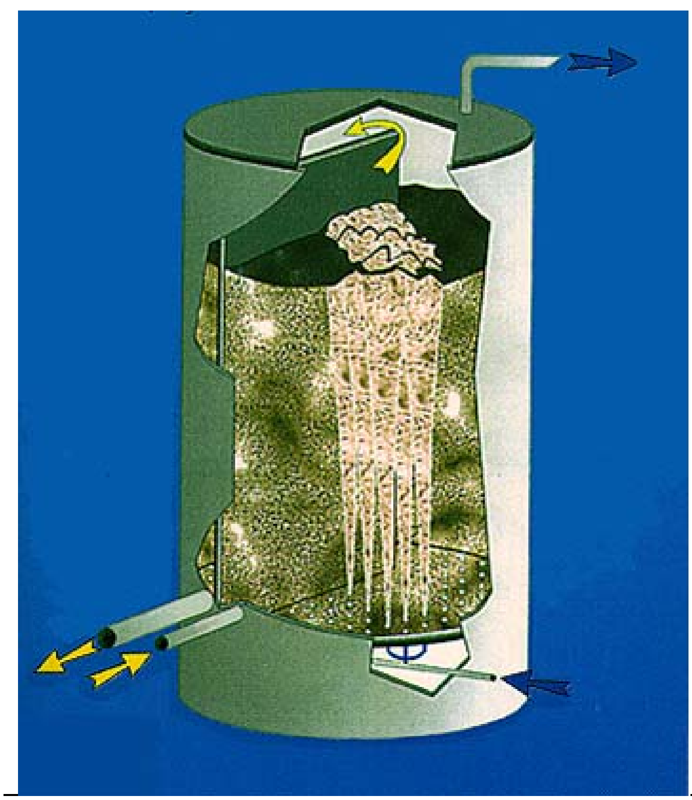
During digester mixing, steam is injected in order to heat up the feedstock to 130°F. There is no heat exchanger in the digester. The concrete digester has the form of a vertical cylinder with a height of 36 ft.

Figure 1.22: Valorga Process



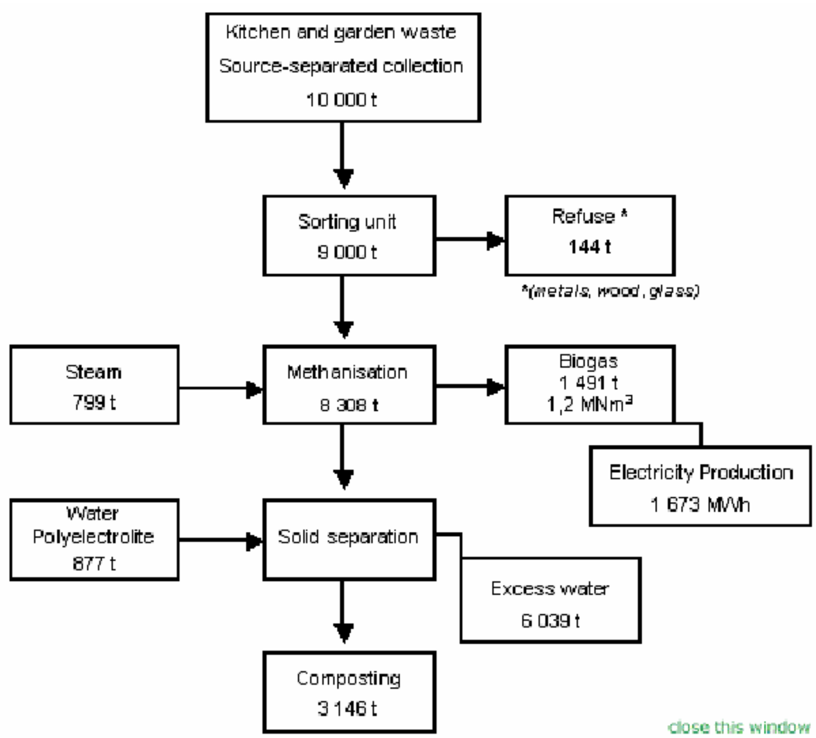
The source separated material is fed into the bottom on one side of a vertical median inner wall and is removed at the other side of the wall at the bottom as well. The wall has a length of 2/3 of the diameter dividing the digester reactor into two halves. The Valorga digester is completely stirred due to its individual stirring sectors, but in total the transportation of the material around the inner partition of the reactor is reported by Valorga to have the character of a plug (piston) flow.

Figure 1.23: Valorga Compressed Biogas Mixing



As shown in Figure 1.23, the digester is fully mixed using a pneumatic compression system. In it, biogas is compressed and injected through a large number of nozzles in the bottom of the digester. The nozzles are divided in 8 to 12 different sectors, each individually operated.

Figure 1.24: Geneva Facility Mass Balance

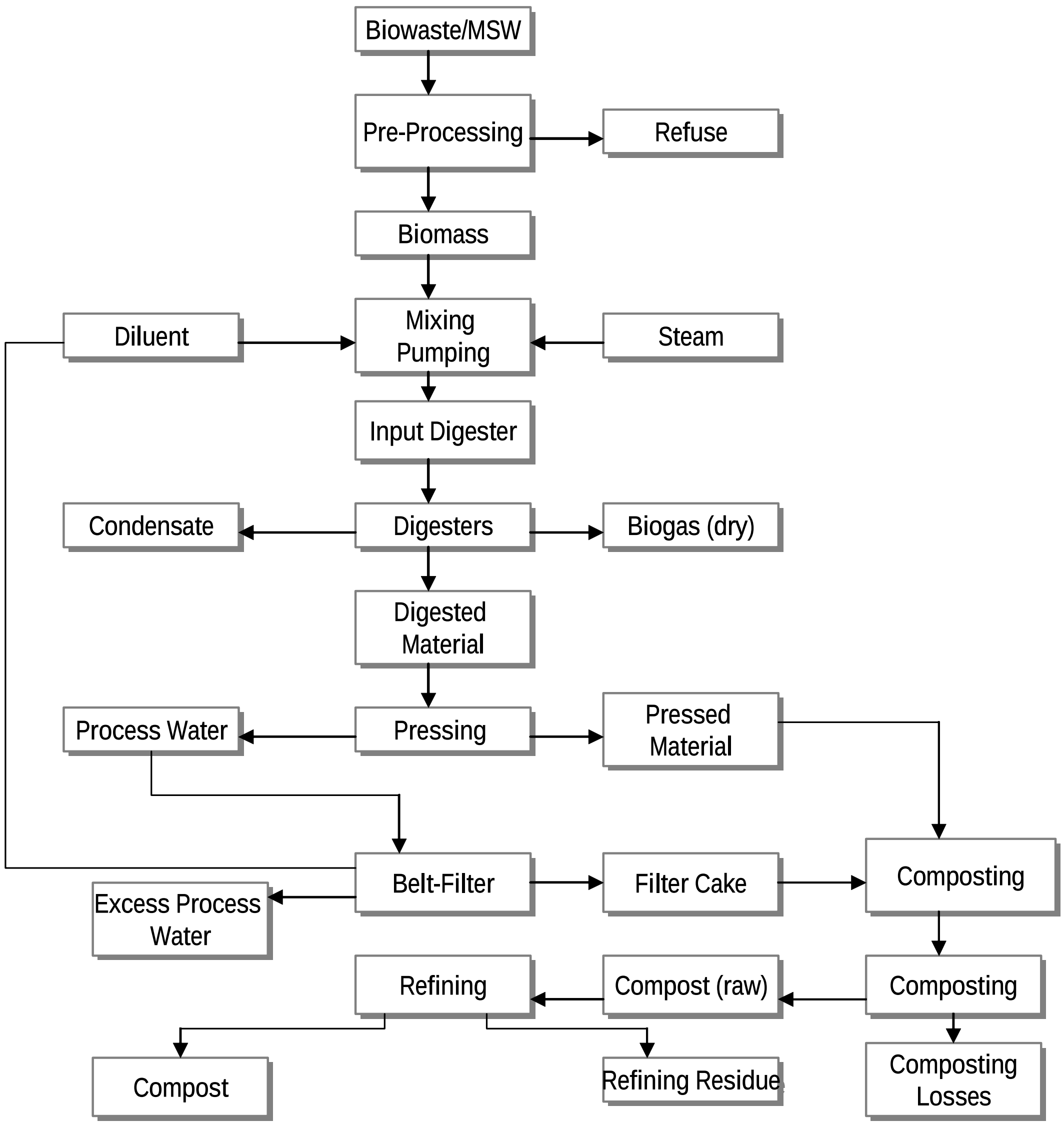


The treated material is removed by the static pressure of the digester through a valve. The digestate is separated by a screw press into a fiber and liquid fraction without the addition of poly-electrolytes. The liquid is further treated: sand is removed by a hydrocyclone and suspended solids are later removed by a belt filter press.

The digester is operated with a rather long HRT of 30 days or more, which increases the volume of the digester reactor. On the other hand, this extra volume gives the digestion process a certain tolerance, i.e., the addition of more waste during peak loads is easily absorbed. The organic matter loading rate is around 0.425 lb of VS/ft^3/day. The incoming feedstock should have a TS content of greater than 25%. At lower values, sedimentation could occur in the digester reactor. The process flow mass balance is provided in Figure 1.24 above for reference.

Another Valorga facility recently became operational in Bassano Del Grappa, Italy. It is designed to accept up to 55,000 tons per year of MSW and biowaste. The materials and energy balance are likely to be similar to Bluestem's AD needs (See Section 4). A process flow diagram is provided below to characterize their process.

Figure 1.25
Valorga Process Flow Diagram



The above process flow diagram effectively characterizes the overall AD process.

1.5.3.4 Aarburg, Switzerland (Dranco)

After mechanical separation using a mesh size of 1.5 inches in this Dranco AD facility, the OFMSW is steam heated and fed into the digester using comparable equipment to that used by the Valorga process. However, about 10% of fresh material is externally mixed with 90% of recycled digestate.

Figure 1.26: Aaburg AD Facility

The vertical enamel steel tank has a cylindrical form (see Figure 1.26) with a conical bottom of 45° angle. The feedstock is fed through the top; the digestate removed at the lowest point. There is neither any mixing nor any heating inside the AD reactor. However, the feedstock is fully recycled within two days or less, which corresponds to a smooth external mixing. The digester is operated at 130°F, with a TS content of 18%-35%. The HRT may vary from 18 to 24 days with average organic loading rates of 0.312-0.437 lb VS/ft^3/day. Like Valorga, Dranco feeds the digester five days a week.

The treatment of the digestate is absolutely identical to the Valorga process. In Aarburg, the post-treatment composting of the fiber fraction is done at different composting units that deliver part of their waste to the plant.

1.5.4 Dry Two-Step, Two-Phase Process

There is presently only one dry two-step, two-phase process being commercially used. It is a so-called “Percolation” process that was developed during the 1990’s. Its major application is for full MSW or grey waste. Recent trials, however, have proven that the process works equally well for green waste. Feedstock preconditioning is essential.

This process works more quickly when compared to one-step or liquid two-step digestion processes. The hydrolysis step is operated under aerobic conditions, which reduces the organic degradation time considerably. The digestion period itself is also much shorter than in most of the other processes, because only the liquid fraction is anaerobically treated. This can be done in either a packed bed digester or in an anaerobic filter where the HRT can be reduced to two days or even less. As a consequence, the biogas yield is slightly lower than in comparable CSTRs having an HRT of 20 (or more) days. Roughly, the yield from a percolation system accounts for about 70%-80% of methane produced using other methods with similar feedstocks.

1.5.4.1 Buchen, Germany (ISKA)

Figure 1.27 depicts the mechanical separation, nitrification/dentrification tank and digester of the Buchen Plant.

Figure 1.27: Buchan AD Plant

In Buchen, a drum sieve having a mesh size of 3.5 to 6.0 inches is used to separate the OFMSW from plastics, papers, and textiles. Before biological treatment, the metals are removed by a magnetic belt. The captured reject material is a dry, high-energy content RDF that is either landfilled or incinerated. The organic rich underflow is fed into the percolator.

The percolator is a horizontal, continuously operating cylindrical reactor made of steel (see Figure 1.28). It is equipped with a central mixer, shown in Figure 1.29, and a hydraulically-powered scraper located over a grate. It is fed with the OFMSW at one end and emptied on the other end after passing through a screw press to dewater the material.

Figure 1.28:Buchen Percolator

Figure 1.29 Interior of Buchen Percolator

The feedstock is alternatively aerated and percolated, and it is intermittently stirred. The percolation water is introduced from the top and removed through screens at the bottom of the reactor. After removal of sand and a fine organic sludge (which is recycled to the percolator), the saturated percolation water is fed into the anaerobic hybrid filter from the bottom and removed from the top. The digestion HRT varies as a function of waste composition, but is usually between two and three days. The liquid is treated in a nitrification/denitrification plant followed by an ultra filtration process, and is either recycled as process water or released into the sewer. During the two day percolation period, one ton of grey waste is reduced to a mass of around 800 pounds.

After leaving the percolator and being separated from the liquid fraction by a press, the recovered solids have a 60% TS content and are dryer than the original fresh material that had a 50% TS content. The solids are typically post-composted in an open windrow. The organic fraction is still high enough to raise the temperature up to 160°F during the composting process. As a result, the material is sanitized and is further stabilized. After the three week post-composting process, the solids are further dried to an 80% TS content.

This solid material is easy to separate by sieving it into separate fiber, inert, metal, and plastic fractions. The sorted non-fiber material can then either be recycled, landfilled or incinerated depending upon its purity. The fiber is generally used for landfill cover, or for soil remediation purposes.

Depending on the input composition, the liquid fraction produces biogas at a rate of 1,400-2,650 ft^3/ton MSW. With a total treatment time of five days (two days of percolation and three days of digestion), a comparable amount of biogas is produced as with a dry one-step digestion system during a 20 day HRT.

1.6 Summary

1.6.1 Wet vs. Dry Digestion

As reflected above, one-step wet systems are primarily designed to co-digest source separated OFMSW with a liquid substrate such as manure or sewage sludge. They are not typically used for the AD of the full OFMSW stream.

Generally, wet digestion is only economically feasible when the residual liquids can be reused. Since European MSW usually contains relatively high concentrations of heavy metals, this substrate is not generally available for use on agricultural fields.

Constrastingly, the dry one and two-step systems can usually be effectively used for management of OFMSW and grey waste.

Section 2
SURVEY OF ANAEROBIC DIGESTION FACILITIES

Because there are no commercial-scale AD facilities operating in the U.S. that use MSW or the organic fraction of MSW (OFMSW) as feedstock, an extensive survey was initiated of AD facilities in Europe. Facilities digesting at least 2,500 tons/year of either the OFMSW or Organic Industrial Waste (OIW) as its feedstock, or those feedstocks co-digested with other organic materials, were selected for the survey. More than 60 facility operators or system providers representing AD facilities from ten different European countries were surveyed. All of the AD systems described in Section 1 of this report were included. The AD plants surveyed were either "dry" systems treating organic residues in concentrations of 15% to 35% TS, or "wet' systems with TS of 15% or less. Dry systems are also commonly referred to as "High-Solids Anaerobic Digestion" (HSAD) systems.

2.1 Survey Development

As an initial step, the R.W. Beck Project Team (Beck) developed a questionnaire that was translated into three languages: English, French and German. A copy of the survey is included in Appendix A for reference. The survey requested the following information:

- General facility description (i.e., facility operator, owner, and the system provider);
- Identification of feedstocks and substrates;
- AD process used and critical issues faced during operation;
- Description of the digestate;
- Biogas generation and utilization; and
- Available facility costs information.

2.2 Survey Evaluation

A total of 64 surveys were forwarded to AD facility representatives. Fourteen responses were received. This equates to a response rate of 22%. Of those responding, eleven are operators of private facilities and three represent public facilities. Provided below in Table 2.1 is a list of the facilities that responded to the survey.

Table 2.1
Responding AD Plants

Provider	Operator and Location
BTA	City of Karlsruhe, Germany
	Karlsruhe, Germany
	City of Baden-Baden, Germany
	Baden-Baden, Germany
	Ganser Entsorgung
	München County, Germany
Dranco	VEGAS
	Aarburg, Switzerland
Kompogas	Braunschweiger Compost AG
	Braunschweig, Germany
	Kompogas AG
	Rümlang, Switzerland
	Kompogas AG
	Bachenbülach, Switzerland
	Kompogas Samstagern AG
	Samstagern, Switzerland
	Region Furttal-Limmattal AG
	Otelfingen, Switzerland
	Bioverwertungs AG
	Niederuzwil, Switzerland
Linde BRV	Abfallbeseitugungs GmbH
	Lippe, Germany
	Alfred Müller AG
	Baar, Switzerland
Valorga	Etat de Genève
	Geneva, Switzerland
ISKA	T-Plus
	Buchen, Germany

It is interesting to note that from the six different providers that participated in the survey, only two (BTA and ISKA) have wet digestion systems. Linde, who also provides liquid systems thorough its Linde-Dresden-KCA subsidiary, only responded regarding its HSAD system. This is not viewed as a major deficit since the project team has sufficient background experience to describe the various wet systems.

All systems represented, except for one, process source separated organic wastes. Only one facility that processes grey waste responded. Grey waste is a specific description of an MSW waste stream from which at least a part of the organic fraction has already been removed. Usually the so-called biowaste (mainly kitchen waste) and yard waste (branches, leaves, etc.) have already been source separated. The grey waste typically contains 30% to 50% organic material. However, the easy digestible fraction has been removed. As a result, the biogas potential is far lower for grey waste. The actual completed surveys translated into English, are included in Appendix B for reference.

2.3 Performance Data Interpretation

As shown in Table 2.2, an analysis of production data confirms that grey waste has the lowest biogas potential. In other words, the higher the content of organic materials remaining in the feedstock, the higher the biogas production potential independent of the operational system and its hydraulic retention time. Based on the survey results, from the production data, the range of biogas production potential for a given feedstock from highest to lowest is as follows:

- Predominantly kitchen and food waste;
- Predominantly yard waste; and
- Predominantly other feedstocks.

Table 2.2
Performance Data of AD Plants

Location	Waste Type*	Waste Tons/Year	Ft^3 Digester	Ft^3 Gas Production	Ft^3 Biogas/Ton	Ft^3 Gas/Ft^3 Digester/Day	Lbs./Day/Ft^3 Digester
Aarburg	Yard	12,128	52,973	28,605,150	2,359	1.48	1.25
Baar	Yard	4,410	16,951	13,419,700	3,043	2.17	1.43
Bachenbülach	Yard & Food	9,482	18,364	30,017,750	3,166	4.48	2.83
Baden-Baden	Food & Kitchen	7,166	211,890	51,206,750	7,146	0.66	0.19
Braunschweig	Kitchen	17,640	59,329	60,035,500	3,403	2.77	1.63
Buchen	MSW	110,250	141,260	141,260,000	1,281	2.74	4.28
Geneva	Yard	13,230	35,315	42,378,000	3,203	3.29	2.05
Grindsted**	Biosolids & Food	38,036	98,882	22,954,750	603	0.64	2.11
Holsworthy**	Manure & Food	160,965	282,520	137,728,500	856	1.34	3.12
Karlsruhe	Yard & Kitchen	8,820	47,675	30,935,940	3,507	1.78	1.01
Lemgo	Yard & Kitchen	37,485	90,053	134,197,000	3,580	4.08	2.28
München	Yard & Kitchen	27,563	84,050	52,972,500	1,922	1.73	1.80
Niederuzwil	Yard	11,025	31,784	30,724,050	2,787	2.65	1.90
Otelfingen	Yard	13,781	29,665	38,846,500	2,819	3.59	2.55
Rümlang	Yard & Food	7,718	16,245	28,252,000	3,661	4.76	2.60
Samstagern	Yard & Food	8,489	18,364	28,958,300	3,411	4.32	2.53
Average		30,512	77,207	54,530,774	2,922	2.65	2.10

* When there is more than one type of waste, the higher percentage feedstock is provided first.
** While not a part of the survey, sufficient information was gathered to make consistent comparisons.

As reflected in the data presented in Table 2.2, the average surveyed system treats a waste volume of slightly more than 30,500 tons/year, and has a reactor volume of around 77,000 ft^3. With an average yield of almost 2,900 ft^3/ton of biogas, the average AD system produces slightly more than 6,200 ft^3/hour of biogas.

There are two extremes in the data presented in Table 2.2. For example, the Buchen plant shows an extremely low biogas/ton yield (1,281 ft^3/ton), while having a very high process efficiency in terms of biogas/ft^3 of digester volume (4.28 ft^3/ft^3 of digester). On the other hand, the Baden-Baden plant demonstrates an extremely high biogas/ton yield (7,146 ft^3/ton), while having a very low process efficiency (0.19 ft^3/ft^3 of digester). This may be a result of the fact that the food and kitchen waste used as its principal feedstock are being co-digested with sewage sludge.

2.4 Economic Data Interpretation

With respect to assessing investment cost, there are three specific factors that have an influence:

- Year of construction;
- Size of installation; and
- Type of system.

Of the 14 survey respondents, eight (8) provided information on construction costs. During the course of the information gathering, sufficient information was also gathered on two other facilities using internal Beck resources that can be used for comparison with the surveyed systems. The limited amount of available survey data does not allow an in-depth analysis, but indications as to what a comparable system might cost if deployed in the U.S. Please note the installed costs in Europe, have a significantly different tax structure and cost of living index compared to Iowa. The differences will be more fully addressed in Section 5 of this report.

2.4.1 Year of Construction

Table 2.3 provided below lists capital costs for the development of the surveyed AD facilities. The oldest plant listed in Table 2.3 is the Linde-BRV digester in Baar, which was developed in 1993. It was the first plant of this type built and was considered a demonstration unit. Including the cost of an 8,800 ton/year composting operation, this facility has also been upgraded multiple times. Of course, these add-ons and modifications increase the investment cost dramatically up to installed cost price of $3,175/ton of installed capacity. Even if one were to take into account all of the waste treated each year, this still yields an installed cost of $1,067/ton of installed capacity. Linde-BRV continues to build AD plants today and have reported installed costs of $460/ton (Lemgo). This corresponds to a cost reduction factor of roughly 2.5 accounting for the economies of scale.

Table 2.3
Investment Data of AD Plants

	Type	Provider	Waste tons/year	Installed Cost $	Installed Cost $/ton	Remarks
Baar	Dry	BRV	4,410	14,000,000	3175	w/ 8,800 tons/year composting
Baden-Baden	Wet	BTA	7,166	3,470,000	484	Cogen added
Braunschweig	Dry	Kompogas	17,640	10,200,000	578	w/ post-composting
Buchen	Wet	ISKA	110,250	15,500,000	141	Earlier work cost
Geneva	Dry	Valorga	13,230	5,100,000	385	
Grindsted	Wet	Kruger	38,036	8,860,000	233	
Holsworthy	Wet	Farmatic	160,965	8,000,000	50	
Lemgo	Dry	BRV	37,485	15,600,000	416	w/ building
München	2-Stage	BTA	27,563	10,500,000	381	w/ pre-treatment & planning
Niederuzwil	Dry	Kompogas	11,025	4,100,000	372	w/o air treatment
Otelfingen	Dry	Kompogas	13,781	5,350,000	388	
Average			40,141	9,152,727	228*	

* Weighted Average

As with Linde-BRV, the other system providers were able to accrue considerable cost reductions over the past decade by incorporating continuous process improvements to their systems. This trend is also reflected in Kompogas' facility development experience. Their first operation was installed in 1992 at a cost of approximately $8.4 million with an annual processing capacity of 11,000 tons and an installed cost of $764/ton. Using more refined engineering practices, the plant in Niederuzwil was built for an installed cost of $388/ton. On an installed cost/ton, this experience reflects a reduction in capital expense of nearly 50%.

Many other system developers report similar trends. For example, from earlier analysis, it was found that the first Valorga operation installed in 1992 also had a cost of $8.4 million with an annual processing capacity of 11,000 tons, or $764/ton. One of Valorga’s 1996 facilities has a reported capital expense of $5.6 million with an annual capacity of 22,000 tons, corresponding to an installed cost of $254/ton.

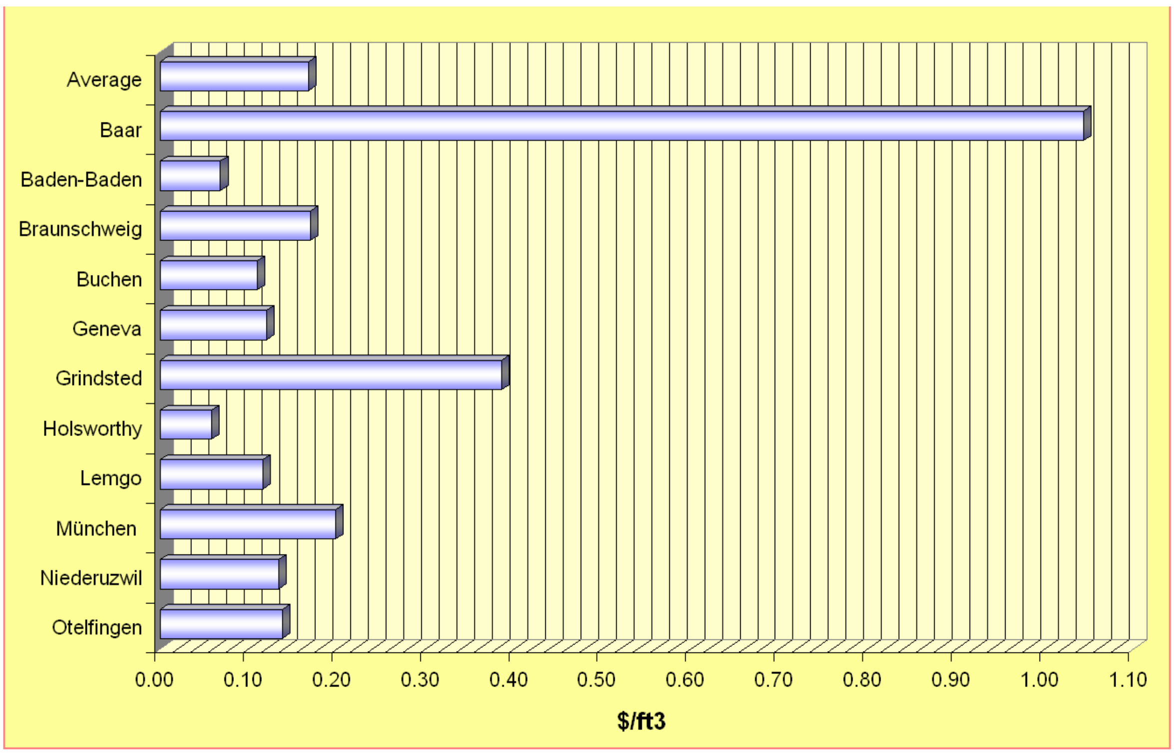
Once again, it should also be noted that the installed costs reflect a “turn-key” facility built in Europe, where investments in some components such as plant machinery, land, and infrastructure are significantly higher when compared to the U.S.

2.4.2 Type of Operation

Most of the digesters are either stirred tank reactors operating under wet conditions with a low total solids concentration (BTA), or HSAD digesters working around 30% TS. However, there are two exceptions. The first is the BTA plant in München, which is a two-step process with hydrolysis as an initial step. The second is ISKA's process, which is a combination of aerobic hydrolysis and a high rate liquid digester.

The specific investment required for both operations are in the mid-range. However, the biogas delivery cost is almost \$0.20/ft^3 of biogas for the BTA plant in München. While this is not conclusive of economic performance, it may be indicative the plant is not operating very efficiently. In addition, only 1.80 pounds/day of feedstock are treated per ft^3 of digester volume. On the other hand, the ISKA plant in Buchen seems to be a more efficient operation with a delivery cost of \$0.11/ft^3 of biogas as 4.28 pounds/day of feedstock are treated per ft^3 of digester volume. Figure 2.1 provides a comparison by facility of the installed capital cost per cubic foot of biogas generated.

Figure 2.1 Biogas Delivery Cost



The bulk of the AD facilities' delivery costs fall between \$.10 and \$.20 per cubic foot of biogas.

2.4.3 Scale of Operation

While limited, the available data does allow for an analysis of installed cost for different processing capacities. Given the available information, Beck conducted a multiple regression analysis for the facility survey results.

The purpose of this analysis was to attempt to quantify some of the economies of scale typically present when building a large, capital-intensive project such as the potential Bluestem project. The multiple regression analysis indicated that on a cost/ton basis of installed capacity, projects with higher installed capacities tend to capture the benefits of economies of scale, and cost less to build on a cost/ton basis than smaller facilities.

After removing certain outliers, various regressions were tested using exponential and logarithmic extensions of the survey data. The regression that resulted in the highest R-squared[1] used tons/year and a square of tons/year to predict total installed cost. This regression produced an R-squared of 76%, with one Standard Deviation of approximately $2.1 Million.[2]

To illustrate the economies of scale, the resulting equation from the regression analysis was used to estimate the total installed costs of facilities capable of processing two different size facilities - 36,000 and 69,000 tons per year (per the available feedstock as outlined in Sections 3 and 4 of the report). The total installed costs of the 36,000 tons/year facility were estimated to be approximately $9.0 million, equating to a cost/ton of approximately $251/ton. The total installed costs for a 69,000 tons/year facility were estimated to be approximately $12.8 million, equating to a cost/ton of approximately $186/ton. As shown in these results, the larger facility reflects an economies of scale, and results in a 26% lower cost per ton than the smaller facility.

The results clearly confirm that economies of scale are reflected in the survey results. This means that while mid-size plants (25,000-34,000 tons/year) do have a lower overall total investment cost, in general larger facilities have a lower investment cost on a per ton basis. As a result, information to be presented later in this report considers the impacts of the economies of scale issue on the potential Bluestem project.

[1] "R-squared" is a statistical output from 0 to 1 that indicates what percent of the variation in the dependent variable (total installed cost in this regression) is attributed to the independent variables (tons/year and ton/year squared in this regression).

[2] While this is a fairly strong correlation, it should be noted that a higher R-squared, and a smaller Standard Deviation could probably be achieved with data from more facilities. Consequently, the regression should be viewed as merely an approximation attempting to capture some of the economies of scale evident in the survey.

Section 3
GENERATORS OF POTENTIAL FEEDSTOCK

3.1 Introduction

The R. W. Beck Project Team (Beck), with input from the Bluestem Solid Waste Agency (Bluestem) staff and the Best Practices Roundtable (Roundtable), developed a written survey to assess the availability of organic materials as feedstock for an anaerobic digestion (AD) project in the Bluestem planning area. A copy of the written survey and relevant cover letters are included in Appendix C for reference. The specific purpose of the survey was to determine the types of organic wastes generated, quantities generated, present management methods, estimated management costs, and level of interest in utilizing AD from the organic waste generators in the Bluestem area. Specific questions included:

- How much total solid waste has your facility produced in the last two years?
- How does your firm currently handle waste collection and disposal?
- Where is the solid waste currently managed?
- What percentage of the waste stream is estimated to be organic or compostable materials?
- Does your facility currently divert the organic waste from disposal for recycling and/or re-use? If yes, what percentage is currently being diverted?
- How is organic waste transported to the end-user?
- Are you paid for the organic waste? If so, how much? If not, how much do you pay to divert the organic waste?
- If you generate organic waste, but don't separate it from the waste stream, what are the barriers to overcome for your organization to separate the organic waste for processing or re-use?

In addition, the generators were asked to complete a table listing the types of waste and the tons generated per year, as well as the tons recycled and/or composted per year.

Beck and Bluestem agreed on a list of forty-eight (48) potential organic waste generators. Those surveyed included:

- Institutions such as hospitals and schools;
- Food processing plants; and
- Large industrial facilities likely to generate organic wastes.

The surveys were forwarded to designated representatives of the identified organic waste generators. The respondents had the option of returning the completed survey via mail or fax, or they could fill out the survey on-line through R. W. Beck's Internet site. It was conveyed to those receiving the survey that all information provided in response to the survey would be reported in aggregate form, not on a company-specific basis. Beck met with representatives from the Roundtable, an association of local industry and environmental technical experts, prior to initiating the survey process to generate support for the project. In addition, a follow-up letter was sent by Bluestem to each targeted generator receiving the survey to solicit their response.

3.2 Survey Results

This section summarizes the survey results and identifies organic feedstock that may be available for AD.

A total of sixteen (16) of the 48 surveys were completed and returned. Most of the survey respondents could be classified as large private industrial and commercial solid waste generators. The data from these responses was compiled, including the tonnages generated and the tonnages recycled for each organic material. Table 3.1 below summarizes the survey responses of the various types and amounts of organic waste generated in the Bluestem area.

Table 3.1
Type and Amount of Organic Waste Generated and Diverted

Type of Waste	Tons Generated	Tons Diverted	Current Diversion Method			
			Tons Composted	Tons Land-Applied	Tons Recycled	Tons Used as a Fuel
Sludges	64,728[1]	64,728	64,728	-	-	-
Other Organic Waste[2]	36,724	36,519	5,696	30,823	-	-
Paper (includes OCC, ONP, Office Paper & Mixed Paper)	1,984	1,678	-	-	1,678	-
Food Waste[3]	44,934	44,144	-	-	16,144	28,000
Yard Waste	362	52	52	-	-	-
Pallets and Other Wood	503	369	-	-	369	-
Fabric	160	104	-	-	104	-
TOTAL:	149,395	147,594	70,476	30,823	18,295	28,000

[1] Per discussions with Bluestem staff, approximately one half of this amount would be available for anaerobic digestion.
[2] Other organic waste includes: Feed; fiber filters; dry starch waste; bathroom towels; filter cake by-product; biomass by-products made of denatured bacterial cell bodies, protein, nitrogen, carbohydrates, phosphorus, copper, zinc, and organic, non-toxic polymers.
[3] Food waste includes waste from manufacturers of food products, as well as cafeteria waste from institutions and industries.

The total waste generated by the companies that responded to the survey was estimated to be 181,508 tons for calendar year 2000. Of that amount, 149,395 tons or 82% was reported as organic waste.

Of the total organic waste generated, the respondents to the survey reported that 147,594 tons or 99% of the organic waste is currently being diverted from disposal (the material is being composted, land-applied, reused, re-manufactured, or used for energy production).

Follow-up telephone calls were made to the largest generators to gather additional data related to the chemical composition of their organic waste and waste by-products. The type of data collected included pH levels, percentage of total solids, and chemical oxygen demand (COD). This information was used as part of the analyses to evaluate biogas yields.

The specific list of those receiving a survey is included in Appendix D for reference. Please note that many small to medium generators of organics were not included in the survey, however, it is recognized that these generators dispose of organic wastes at Bluestem facilities.

3.3 Conclusions

Per the Bluestem Solid Waste Characterization Study (Beck, 2000), organic wastes being landfilled that could serve as potential feedstock for an AD facility are estimated to range from 15% to 25%. Fifteen percent represents food waste and yard waste, whereas the 25% includes food waste, yard waste, and non-recyclable paper. Using FY2002 disposal data for Bluestem, 26,000 to 43,000 tons per year would be potentially available for use as feedstock in an AD facility. Much of this fraction of the waste stream is not presently being source separated and would require either financial incentives or local mandates for the materials to be directed to the facility in a source separated form. As a result, the evaluation focused on large generators of organic materials requiring minimal separation to be used as potential feedstock.

Section 4
CO-PRODUCTS CHARACTERIZATION

4.1 Overview

The co-products of the anaerobic digestion (AD) process are a medium-Btu content biogas and a slurry called digestate. The biogas contains approximately 60%-70% methane and is water saturated. The balance of the biogas mixture is carbon dioxide, and some parts/million (ppm) of hydrogen sulfide.

The digestate consists of undigested solids, cell-mass, soluble nutrients, other inert materials, and water. All digestate contains a recoverable solid fiber with physical attributes similar to those of a moist soil conditioner. Depending on the feedstock, this product may be used as a soil improver or potentially used as a constituent in potting soils. After the fiber is removed, the residual product is a liquid organic substance commonly called "filtrate". Once again depending on the feedstock, filtrate can be spread directly onto agricultural lands for its nutrient value. Filtrate can also be further processed to provide a liquid material commonly called "centrate" and solid product called "cake" which is comprised of the fine suspended solids contained in the filtrate.

The specific quantities and quality of the co-products are directly related to the input material and the actual AD process technology selected. This section of the report is limited to a general discussion of the various co-products from AD when using various viable feedstocks such as the organic fraction of municipal solid waste (OFMSW), source separated organic wastes, sludges, and yard waste.

As discussed in Section 3, key parameters such as Percentage Total Solids[1] (TS%), Volatile Solids[2] as a Percentage of Total Solids (VS%), and pH were requested as part of the survey, but these parameters were not necessarily provided by all the potential organic waste generators.

Because of their likely high-cellulose characterization, paper and fabric do not normally exhibit the chemical composition suitable to the AD process. Thus, this organic fraction of the waste stream for purposes of this analysis was not assumed to be an input into the AD process.

In addition, materials with high TS% concentrations, such as pallets and other wood, were also removed from consideration. Wood wastes are more suited for combustion processes than for AD. Additionally, the fiber recovered following the AD process will possibly require the use of admixtures for bulking purposes. Chipped wood

[1] *n.b.*, TS concentration is the solid material fraction of total feedstock weight.

[2] *n.b.*, VS is the organic fraction of TS, of which a portion is converted into biogas.

would add needed structure to the recovered fiber, and possibly create a value-added processed material that could be sold to local horticulture, landscaping, and site remediation industries.

With additional clarification from the organic generators, materials such as filter cake and dry corn starch waste classified as other organic waste were excluded from consideration as an AD feedstock. In addition to having a high TS%, these materials likely contain less than a 60% VS concentration relative to TS%. As a rule of thumb, materials containing a concentration of less than 60% VS are rarely considered as feedstocks for the AD process.

Table 4.1
"Base Case" Organic AD Feedstocks

	Tons/Year	Tons/Day
Sludges[1]	32,364	89
Other Organic Waste	33,300	91
Food Waste	2,934	8
Yard Waste	362	1
Total	68,960	189

1 Per discussions with Bluestem, this is the total amount that would be available for AD, approximately one-half of the total amount generated

Table 4.1 depicts a "base case" scenario for AD feedstock within the Bluestem planning area. Of the total amount of organic waste generated (149,395 tons/year), about 46% (68,960) tons can be considered as potential AD feedstocks. The portion of the available feedstock secured for use as AD feedstock will likely be a function of proposed contractual arrangements and alternative tip fee pricing at the proposed AD facility. Per the survey, even though most of these materials are not presently being landfilled, present methods of diversion for the sludges and other organic wastes have identified limitations. Consequently a portion of the organics presently being diverted are considered viable feedstock as part of the "base case".

The balance of this analysis is used to present some generalized estimates on the opportunities for recovering methane and other co-products from an AD facility sized to manage approximately 189 tons/day of organic residues. For the purposes of this section, the AD facility is assumed to use a “dry” AD system (i.e. HSAD) that is capable of treating these organic residues in concentration of up to 40% TS.

An HSAD system, as contrasted with “wet” systems that require sometimes significant dilution to operate in their preferred TS concentrations, commonly ranging from 10%-15%. Given the amount of dilution water required to utilize the “wet” systems with the likely organic feedstocks, an increase in overall make-up water was deemed as not preferable. For example, each ton of organic feedstock at a 33% TS concentration would require around 300 gallons of dilution water to achieve a 15% TS concentration. To process 189 tons/day of organic matter would therefore require around 55,000 gallons/day of dilution water. Given the weight of water, this would more than double the mass of waste being treated, a factor of slightly more than 120%.

There are "wet" systems that can recycle significant quantities of dilution water, but some "leakage" must be anticipated if these types of systems are to be used.

4.2 AD Inputs and Outputs

As noted in Table 4.1 above, the "base case" of feedstock within the Bluestem planning area is approximately 68,960 tons/year of organic materials. Per the survey, these materials were determined to be sludge, other organic waste, food waste and yard waste.

4.3 Sludges

Although it is estimated a total of 64,748 tons/year of this material is generated within the Bluestem collection area, only about one-half (89 tons/day), is considered potentially available for use in the AD facility. Based on a recent analytical report, the sludge feedstock has a TS concentration of slightly more than 34%, or nearly 60,400 pounds/day of solid matter in the available fraction. With an average VS concentration of around 88% of TS, it is estimated that the total daily VS production is around 53,000 pounds/day. Total Kjeldahl nitrogen (TKN) was reported to have a concentration of 2,870 mg/kg on a dry weight basis, which converts into a nitrogen concentration of 5.74 pounds/ton. Phosphorus was reported to have a concentration of <150 mg/kg on a dry weight basis, which converts into a phosphorus concentration of 0.30 pounds/ton. The analytical report also found that the sludge has a carbon to nitrogen (C/N) ratio of 286, and a solid pH of 7.3. It was assumed that the AD facility would be capable of converting the sludge feedstock into biogas at a rate of 4.0 ft^3/lb VS, which is a value slightly less than sewage sludge at 4.6 ft^3/lb VS.

4.4 Other Organic Feedstocks

Approximately 91 tons/day of other organic feedstocks is considered potentially available for use by the proposed AD facility. This material is largely a biomass byproduct, consisting of denatured bacterial cell bodies, protein, nitrogen, carbohydrates, phosphorus, copper, zinc, and organic, non-toxic polymers. Unfortunately there were no analytical reports on its composition, so it was assumed to have characteristics similar to the sludge above. With a TS concentration of slightly more than 34%, slightly more than 62,000 pounds/day of solids is assumed to be handled. With an assumed average VS concentration of approximately 88% of TS, it is estimated that the total daily VS production is around 54,500 pounds/day. It was assumed that the AD facility would be capable of converting the other organic feedstock into biogas at a rate of 4.0 ft^3/lb VS. However, a more accurate estimate can be developed based on more detailed characterization of the available sludges.

4.5 Food Waste

Approximately eight tons/day of food waste feedstocks are considered potentially available for use by the proposed AD facility. Unfortunately there were no analytical reports on its composition, so it was assumed to have characteristics similar to those reported by Steffen.[3] Steffen is a credible source on this topic as this report was commissioned by the AD-NETT, which is a network of professionals working in anaerobic digestion of agro-industrial wastes in Europe and Canada. AD-NETT's prime motive is to enable exchange of information and experience and to disseminate this information to relevant organizations, such as potential users and developers.[4]

With an assumed TS concentration of 10%, slightly more than 1,600 pounds/day of solids is assumed to be handled. With an assumed average VS concentration of approximately 80% of TS, it is estimated that the total daily VS production is almost 1,300 pounds/day. Steffen also reported that food remains would be capable of being converted into biogas in the range of 8.0-9.6 ft^3/lb VS; the midpoint value was assumed for this analysis. While the exact nature of the food wastes is unknown, raw garbage has been reported having a C/N ratio of 25.[5]

4.6 Yard Waste

Approximately one ton/day of yard waste feedstock is considered potentially available for use by the proposed AD facility. Unfortunately there were no analytical reports on its composition, so it was assumed to have the average characteristics for leaves, garden waste and grass reported by Steffen.[6] With an average TS concentration of 58%, slightly more than 1,100 pounds/day of solids is assumed to be handled. With an assumed average VS concentration of around 90% of TS, it is estimated that the total daily VS production is slightly more than 1,000 pounds/day. The average conversion of yard wastes into biogas was estimated to be the midpoint value of 5.9 ft^3/lb VS. The average yard wastes C/N ratio was calculated to be 68. It should also be noted that yard waste is a seasonal feedstock. If the substrate is composed of easily degradable materials, biogas production could be slightly higher. However, if the substrate is composed of high lignin content materials, biogas production is likely to be less.

4.7 Annual and Daily Feedstock Flows

Given the four feedstocks described above, it appears that approximately 68,960 tons/year (189 tons/day) can be considered potentially available for use by the proposed AD facility. Recognizing the limited information available on its exact

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[3] Steffen, R; Szolar, O. and Braun, R. 1998. *Feedstocks for Anaerobic Digestion.* Institute for Agrobiotechnology Tulin, University of Agricultural Sciences, Vienna.

[4] http://www.ad-nett.org/

[5] National Academy of Sciences. 1977. *Methane Generation from Human, Animal, and Agricultural Wastes.* Washington, DC.

[6] *Supra*, Note 5.

composition, the overall feedstock is calculated to have a TS concentration of 24%, or slightly more than 102,000 pounds/day of solid matter. With an average VS concentration of approximately 87% of TS, it is estimated that the total daily VS production is around 102,000 pounds/day. It was also assumed that the AD facility would be capable of VS destruction potential of 50%, and the average conversion into biogas was 5.1 ft^3/lb VS. Excluding water vapor, the hypothetical annual and daily inputs and outputs for the baseline AD facility are presented in Table 4.2 below.

Table 4.2
AD Facility Material Flows

Inputs	Unit	Annual
Feedstock	Tons	68,960
Outputs	**Unit**	**Annual**
Methane	Million Btu	87,800
Digestate	Tons	62,500

4.8 Biogas Production

Biogas production was estimated to be around 400,000 ft^3/day. Further assuming that there are 600 BTU/ft^3 of methane contained in the biogas, the AD plant is capable of manufacturing approximately 87,800 million Btu annually. Assuming an electrical generation efficiency of 35%, the AD facility would be capable of supporting a capacity of approximately 1.02 MW. Assuming a capacity factor of 90%, some 8.18 million kWh could be generated annually. Also, there is increasing interest by municipalities in using biogas as an alternative transportation fuel. Assuming that a gallon of diesel fuel contains 130,000 Btu (lower heating value), then the AD facility has the capacity to manufacture the equivalent of more than 750,000 gallons of diesel fuel equivalent.

4.9 Solids Separation

In addition to the biogas, the AD facility would annually produce about 62,500 tons of digestate. Digestate recovered from the AD plant would contain a recoverable solid fiber with physical attributes similar to those of a soil conditioner, and would have a total solids concentration of 35%-45%. Fiber is usually recovered by mechanical solids separation equipment such as screw presses or vibrating screens. After separation in a processing facility, the fiber would be combined with appropriate admixtures and composted in windrows for 10 to 20 days until final maturation. After final maturation, the composted fiber product could be hauled off-site for use on agricultural land.

After the fiber is separated, a liquid fraction called “filtrate” is created. A portion could be recycled as make-up water for the AD plant. Depending upon the feedstock and applicable regulations, filtrate can be spread directly onto agricultural lands for its nutrient value.

Table 4.3
AD Plant Material Flows

Inputs	Unit	Annual	Daily
Digestate	Tons	62,500	171
Outputs	**Unit**	**Annual**	**Daily**
Fiber	Tons	18,137	50
Filtrate	Tons	44,422	121

Projected daily and annual inputs and outputs for the solids separation operation are presented above in Table 4.3. For the purposes of this section, the solids separator is assumed to be a mechanical screw press that operates with an 85% separation factor and produces a fiber with 45% TS concentration. The separation facility is assumed to be capable of processing around 171 tons of digestate/day. Fiber production is estimated to be 50 tons/day and filtrate production is estimated to be 121 tons/day.

As noted above, the TKN contained in sludge and assumed to be contained in the other organic waste is 5.74 lb/ton/day. Phosphorous (P) is estimated 0.30 lb/ton/day. Assuming an average 95% recovery factor, the solids separation operation is capable of recovering 178 tons of TKN and 21 tons of P annually. It is therefore estimated that the total daily TKN recovery is around 0.49 tons and total daily P recovery is around 0.6 tons. It is calculated that 36% of the nutrients are contained in the fiber and 64% in the filtrate.

Total nutrients leaving the system in the various forms are estimated within ±5%, but may be up to ±25% of the amount entering the digester. More exact analysis of the mass balance of the system should be completed during the final engineering phase of the project if it moves forward to this phase of development.

4.10 Carbon Benefits

One of the key elements that results from using an AD system are its environmental benefits. While an exact quantification of all potential environmental benefits is beyond the scope of this study, a preliminary estimate has been attempted to estimate carbon-equivalent (CE) savings.

Table 4.4
Partial Carbon Benefits

	Metric Tonnes	GWP Coefficient	Metric Tons CE
Digester Methane	2,035	5.19	10,560

As presented above in Table 4.4, a co-product benefit that results from using the AD process is a reduction in Greenhouse Gas (GHG) emissions. Not all GHG emissions have the same atmospheric reactivity. Therefore, the carbon emissions are multiplied by a Global Warming Potential (GWP) to achieve a consistent CE[7].

Methane recovered from an AD process is a potent GHG, having a GWP of 21. This means that a given mass of methane could increase the atmosphere's radioactive forcing by an amount 21 times more than the same mass of CO2. Methane has a mass of 19.178 grams/standard cubic foot. The AD facility is estimated to produce 245,500 standard cubic feet/day of methane. Assuming methane has 980 BTU/ft^3 (lower heating value), this amount of recovered methane will have a mass of 2,035 metric tons. After adjusting for CE by multiplying by a GWP of 21 reflects that recovering all the methane from the AD plant potentially reduces potential GHG emissions by approximately 10,560 metric tons CE.

4.11 Summary

The co-products of the AD process are a medium-Btu content biogas and a slurry called digestate. The biogas contains approximately 60%-70% methane and is water saturated. The balance of the biogas mixture is carbon dioxide, and some parts/million (ppm) of hydrogen sulfide. The digestate consists of undigested solids, cell-mass, soluble nutrients, other inert materials, and water.

The specific quantities and quality of the co-products are directly related to the input material and the actual AD process technology selected.

The projected AD facility is assumed to be an HSAD system that is capable of treating these organic residues in concentration of up to 40% TS. An HSAD system is contrasted with "wet" systems that sometimes require significant dilution to operate in their preferred TS concentrations, commonly ranging from 10%-15%.

Recognizing the limited information available on its exact composition, the overall feedstock is calculated to have a TS concentration of 24%, or slightly more than 102,000 pounds/day of solid matter. With an average VS concentration of approximately 87% of TS, it is estimated that the total daily VS production would be approximately 102,000 pounds/day. It was also assumed that the AD facility would be capable of VS destruction potential of 50%, and the average conversion into biogas would be 5.1 ft^3/lb VS.

[7] *n.b.*, carbon is determined by its proportion to the molecular weight of CO2, 12/44.

Biogas production was estimated to be around 400,000 ft^3/day. Further assuming that there are 600 BTU/ft^3 of biogas, the proposed AD plant would be capable of manufacturing approximately 87,800 million Btu of methane annually. This amount of methane is capable of supporting a capacity of approximately 1.02 MW or the equivalent of more than 750,000 gallons of diesel fuel equivalent.

A key benefit of the AD system is a reduction in GHG emissions. The recovering of methane from the proposed AD plant potentially reduces GHG emissions by approximately 10,560 metric tons of CE.

Section 5
POTENTIAL AD FACILITY COST ANALYSIS

5.1 Overview

Per the "Base Case" as described in Section 4, coupled with the need to evaluate economies of scale benefits, Beck conducted a cost analysis of two potential sized AD facilities – 69,000 tons per year (TPY) and 36,000 TPY. As identified in Section 4, the various organic feedstocks and their quantities composing the Base Case are provided below in Table 5.1.

Table 5.1
Base Case Organic AD Feedstocks

Types/Materials	Tons/Year
Sludges	32,364
Organic Industrial Wastes	33,300
Food Waste	2,934
Yard Waste	362
Total	68,960

To minimize the risks of relying on a minimal number of sources of feedstock, an alternative AD Facility scenario was formulated. For this scenario, it was assumed only 50% of the total quantities of sludges and organic industrial wastes and 100% of the food and yard wastes identified as part of the Base Case scenario would be directed to the AD facility. The applicable types and quantities of feedstocks composing the 36,000 TPY AD facility "Alternative Case" scenario are provided below in Table 5.2.

Table 5.2
Alternative Case Organic AD Feedstocks

Types/Materials	Tons/Year
Sludges	16,182
Organic Industrial Wastes	16,650
Food Waste	2,934
Yard Waste	362
Total	36,128

For purposes of the AD facility cost analysis, the Base Case has been characterized as a Large AD facility and the Alternative Case as a Mid-Sized AD facility. Provided below is a table that summarizes the materials process flows for these two facility options.

Table 5.3
Material Process Flows

	Mid-Size AD Facility	Large AD Facility
Inputs		
Feedstocks (TPY)	36,128	68,960
Output		
Electricity (Net KWh)	4,400,000	7,900,000
Thermal (Net MBtu)	149,000	26,400
Digestate		
Fiber (TPY)	8,700	16,100
Filtrate (TPY)	24,700	47,900

The material process flows identified above for the Mid-Sized Facility includes the following assumptions:

- produces approximately 225,000 cubic feet/day of biogas; and
- produces 49.3 billion Btu/year of energy assuming 600 Btu/cubic feet of biogas.

The material process flows identified above for the Large AD Facility includes the following assumptions:

- produces approximately 404,700 cubic feet/day of biogas; and
- produces 88.6 billion Btu/year of energy assuming 600 Btu/cubic feet of biogas.

The material process flows identified above also include the overall following assumptions:

- net KWh calculated by subtracting parasitic electrical requirements from projected gross electricity produced;
- quantities of digestate produced totals approximately 92% of quantity of inputs;
- digestate is composted of approximately 25% fiber and 75% filtrate by weight; and
- the net thermal MBtu is calculated by subtracting the digester's parasitic heating requirements from projected gross thermal MBtu produced.

5.2 Methodology

To complete the potential AD Facility cost analysis, we undertook the following steps:

1. Developed an integrated materials flow and financial model to project energy production, materials flow, facility construction and operation, costs, and anticipated revenues;
2. Reviewed AD facility survey results to estimate per ton installed capital costs;
3. Evaluated per ton installed capital costs to determine economies of scale associated with varying AD facility sizes;
4. Calculated projected capital costs for construction and installation of a Mid-Sized AD Facility and a Large AD Facility;
5. Developed conceptual engineering cost estimates for both Mid-Sized and Large AD Facilities as a comparison to the calculated projected capital costs;
6. Identified the scope of the revenues and expenses associated with an AD Facility;
7. Developed a set of financial pro formas for a twenty-year planning period for both AD Facility scenarios;
8. Conducted sensitivity analyses to identify critical variables; and
9. Characterized the financial results to determine the financial viability of the proposed project.

5.2.1 Integrated Materials Flow/Financial Model

The integrated materials flow/financial model was used to project the outputs as outlined in Table 5.3. Both scenarios assume the conversion of biogas to generate electricity. In addition, hot water recovered from the AD process potentially could be used to displace natural gas as a fuel for heating equipment or facilities. The digestate or residuals from the process as outlined in Section 4 of the report potentially could be used as a soil conditioner. The model offers an opportunity to model multiple scenarios because of the ability to vary facility size, biogas production, and the various values of expenses and revenues.

5.2.2 AD Facility Construction and Installation Costs

Two methods were used to estimate the AD facility capital costs. First, the survey results were reviewed and a multiple regression analysis was conducted. As a means for comparison, a set of conceptual engineering cost estimates were developed.

Because there are no commercially operating AD facilities in the United States using OFMSW as feedstock, a survey of AD facilities in Europe was completed as outlined in Section 2. Table 2.3 identifies the weighted average installed costs for the eleven facilities providing facility cost information to be $228 per ton. A multiple regression analysis was conducted to determine the correlation between the size of facilities and per ton costs. As discussed in Section 2, a fairly strong correlation was found reflecting that larger AD facilities tend to capture benefits of economies of scale.

The results of the multiple regression analysis were used to estimate "turn-key" installation costs of the identified facility scenarios. To simplify the analysis, the size of the facilities have been rounded to equal 36,000 TPY and 69,000 TPY. The results of the analysis as it applies to the two potential facility scenarios are provided below in Table 5.4.

Table 5.4
Projected AD Facility Installation and Construction Costs
Survey Analysis
($)

	Mid-Size	Large
Per Ton Turn-key	251	186
Total Facility	9.0 million	12.8 million

Conceptual level engineering cost estimates were developed for both the Mid-Size and Large AD Facility scenarios. Key assumptions included:

- no direct costs for land for facility site;
- two-stage, high-solids, dry, continuous AD process utilized;
- hydrogen sulfide scrubber used for gas treatment;
- 860 kW diesel engine for converting biogas to energy;
- step-up transformers for electricity;
- unenclosed tipping areas; and
- indirect costs limited to engineering, site evaluation, and start-up support.

Provided below in Table 5.5 are the conceptual level engineering costs estimates for the Large AD Facility.

Table 5.5
Large AD Facility
Conceptual Level Cost Estimate

Description	Total Amount
Indirect Costs	
Engineering	307,050
Construction Management	54,000
Site Evaluation	13,575
Start-up Support	165,025
Total	539,650
Procurement	
Valves and Specialties	1,579,177
Transformers	40,829
Control Panel	304,155
Mixers	750,888
Water Heater and Pumps	167,943
CHP Unit	1,561,575
Tanks	3,573,277
Gas Storage and Treatment	2,028,074
Instrumentation	621,956
Total	10,627,874
Construction	
General	954,840
Electrical	344,779
Mechanical	967,612
Total	2,267,231
Total Construction Costs	13,434,755
Contingency	806,085
Total Installed Cost	14,240,840

Without the contingency factor, the conceptual level engineering cost estimates are within 5% of the estimate developed using multiple regression. The Large AD Facility conceptual level engineering cost estimate reflected a total of $14.2 million for installed capital costs as compared to $12.8 using the survey results analysis.

Provided below in Table 5.6 is the conceptual level engineering cost estimates for the Mid-Sized AD Facility.

Table 5.6
Mid-Sized Facility
Conceptual Level Cost Estimate

Description	Total Amount
Indirect Costs	
Engineering	192,500
Construction Management Labor	40,000
Site Evaluation	7,950
Start-up Support	113,700
Total	354,150
Procurement	
Valves and Specialties	1,058,110
Transformers	26,423
Control Panel	254,426
Mixers	475,101
Water Heater and Pumps	115,508
CHP Unit	908,950
Tanks	2,104,520
Gas Storage and Treatment	1,457,671
Instrumentation	406,690
Total	6,807,399
Construction	
General	616,350
Electrical	281,750
Mechanical	715,248
Total	1,613,348
Total Construction Costs	8,774,897
Contingency	658,117
Total Installed Cost	9,433,014

Without the contingency factor, the conceptual level engineering cost estimates are within 2.5% of the estimate developed using multiple regression. The Mid-Sized Facility conceptual level engineering cost estimates reflected a total of $9.4 million for installed capital costs as compared to $9.0 million using the survey results analysis.

The detailed cost estimates for both conceptual facilities are included in the Appendix for reference.

The total AD Facility costs for the Mid-Size and Large AD facility scenarios were then incorporated into the financial pro formas to evaluate the financial viability of the projects.

5.2.3 Revenues and Expenses

Before initiating the development of the pro formas for the operating results, the scope of the revenues and expenses needed to be characterized. The revenues for an AD Facility are likely to include:

- electricity sales;
- thermal energy sales;
- feedstock tip fees; and
- fiber and filtrate sales.

For purposes of this cost analysis, the following revenues were included:

- electricity sales (3.1/kWh);
- thermal energy sales ($6.00 MMBtu);
- sludge tip fees ($15.00/ton);
- organic industrial waste tip fees ($15.00/ton);
- food waste tip fees ($15.00/ton); and
- yard waste tip fees ($15.00/ton).

Due to the uncertainty of the characteristics of the digestate and availability of other material substitutes, no revenues were projected from reuse of the digestate.

The operating expenses for an AD facility are likely to include:

- fiber hauling and disposal costs;
- filtrate pumping and treatment costs;
- facility labor;
- engine plant operations and maintenance; and
- digester plant operations and maintenance.

For purposes of this cost analysis the following operating expenses were included:

- fiber hauling costs ($3/ton);
- filtrate pumping and treatment costs ($.075/gallon);
- facility labor ($17.80 – $19.00 per hour);
- engine plant operations and maintenance ($1.25/KWh);
- digester plant operations and maintenance (2.25% of capital and installation costs); and
- contingency factor (10% of annual operating costs).

The analysis assumes a cost to haul the fibers, but no cost for disposal. The fiber would likely be blended with other compost by-product at a composting facility for reuse as a soil conditioner. However, markets for compost are presently limited and it was assumed utilization of these materials was not likely to generate either revenues or expenses. If these materials needed to be land applied, an additional $10 to $15 a ton would need to be added to the overall operating expenses.

As for the filtrate, it was assumed that filtrate that is not reused as make-up water would be conveyed to the Cedar Rapids Water Pollution Control Facilities (CRWPC) for treatment and disposal.

As for labor, the two facility scenarios will have different staffing requirements. Both will require a facility manager coupled with a set of laborers. The analysis assumes $25 an hour for a manager position and $16 an hour for laborer positions. Both of these estimates assume approximately 30% to 40% of the hourly rate for benefits. For the Large AD Facility, the analysis assumes the need for one manager and four laborers. For the Mid-Size AD Facility, the analysis assumes the need for one manager and two laborers. This estimate is based on staffing requirements for similar size AD facilities in Europe and requirements for similar types of solid waste facilities in the United States.

As for the engine plant, the 1.25¢ kWh is a reasonable estimate based on operating similar methane-to-energy equipment at landfill gas (LFG)-to-energy facilities. The type of engines to be used at the AD facility will be very similar. The cost estimate is based on actual LFG-to-energy facility operating costs.

As for the digester plant operations and maintenance costs, 2.25% of capital costs are based on actual operating costs of similar AD facilities in Europe.

A 10% contingency factor has been included because these are considered planning level expenses.

5.2.4 Financial Pro Formas

A set of financial pro formas were developed to determine the net present value (PV) over a 20 year planning period. The net PV is determined by calculating the cumulative PV of the revenues less PV of the operating and amortized capital costs. Ultimately, a net gain or loss is projected.

In addition to the revenue and expense assumptions identified above, the following additional assumptions were used as part of the analysis:

- Annual Inflation Rate – 3.0%
- Present Value Rate – 5.0%
- Waste Stream Annual Growth Rate – 3.0%
- Annual Energy Rate Escalation – 1.0%
- Tip Fee Escalation Rate – 1.0%

Based on review and evaluation of two seasons of CRWPC facilities' electric power costs from Alliant Energy, it appears that the average annual rate paid in 2002 was $.031/kWh to $.034/kWh. An average annual rate of $.031/kWh was used to provide a conservative analysis.

Table 5.7
Pro Forma Operating Results
PV Profit (Loss)
($000)

Large AD Facility		Mid-Size AD Facility	
With Electric Power and Thermal Energy Revenues	W/O Thermal Energy Revenues	With Electric Power and Thermal Energy Revenues	W/O Thermal Energy Revenues
717	(2,187)	(2,587)	(4,223)

The results of the PV analysis reflect a positive net cash flow for the Large AD Facility when revenues are included for the sale of electricity and thermal energy revenues.

5.2.5 Sensitivity Analyses

As reflected above in Table 5.7, the analysis also included evaluating the PV with and without thermal energy revenues. It is unlikely that the hot water can be sold to an end-user for displacement of natural gas and therefore it was imperative to model the operating results with and without such revenues.

To determine the impact on the pro forma operating results of variations in several of the critical assumptions, a set of sensitivity analyses were conducted. A worst case and best case for each assumption were identified respectively as follows:

- annual inflation rate – 6% and 1%;
- present value rate – 8% and 3.5%;
- waste stream annual growth rate – 0% and 4.5%;
- annual energy rate escalation – 0% and 2.5%; and
- tip fee escalation rate – 0% and 2.5%.

In addition, the following additional two scenarios reflecting a combination of the above were included in the analysis.

- high inflation, high PV, low waste growth, high energy, annual rates, and high tip fees; and
- low inflation, low PV, high waste growth, low energy annual rates, and low tip fees.

Table 5.8 below reflects the results of this analysis.

Table 5.8
AD Facility Cost Analysis Summary[1]

	Large Facility						Mid-Sized Facility					
	Worst Case		Expected Case		Best Case		Worst Case		Expected Case		Best Case	
	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*	20-Year PV Profit *($000)*	20-Year Profit/ton *($/ton)*
Without Thermal Energy Revenues												
Base Assumptions	NA	NA	(2,187)	(1.11)	NA	NA	NA	NA	(4,223)	(4.08)	NA	NA
Variations in Inflation Rate [2]	(4,658)	(2.36)	(2,187)	(1.11)	(951)	(0.48)	(5,738)	(5.54)	(4,223)	(4.08)	(3,465)	(3.34)
Present Value Rate [3]	(5,075)	(2.57)	(2,187)	(1.11)	(321)	(0.16)	(5,666)	(5.47)	(4,223)	(4.08)	(3,303)	(3.19)
Waste Stream Growth Rate [4]	(6,155)	(4.25)	(2,187)	(1.11)	367	0.16	(6,298)	(8.30)	(4,223)	(4.08)	(2,888)	(2.37)
Utility Rate Escalation [5]	(2,450)	(1.24)	(2,187)	(1.11)	(1,733)	(0.88)	(4,372)	(4.22)	(4,223)	(4.08)	(3,966)	(3.83)
Tip Fee Escalation [6]	(3,816)	(1.93)	(2,187)	(1.11)	644	0.33	(5,077)	(4.90)	(4,223)	(4.08)	(2,740)	(2.64)
Poor Economic Conditions [7]	(5,209)	(3.60)	(2,187)	(1.11)	NA	NA	(5,920)	(7.80)	(4,223)	(4.08)	NA	NA
Strong Economic Conditions [8]	NA	NA	(2,187)	(1.11)	1,620	0.70	NA	NA	(4,223)	(4.08)	(2,169)	(1.78)
With Thermal Energy Revenues												
Base Assumptions	NA	NA	717	0.36	NA	NA	NA	NA	(2,587)	(2.50)	NA	NA
Variations in Inflation Rate [2]	(1,755)	(0.89)	717	0.36	1,952	0.99	(4,103)	(3.96)	(2,587)	(2.50)	(1,829)	(1.77)
Present Value Rate [3]	(2,805)	(1.42)	717	0.36	3,004	1.52	(4,387)	(4.23)	(2,587)	(2.50)	(1,430)	(1.38)
Waste Stream Growth Rate [4]	(3,911)	(2.70)	717	0.36	3,695	1.59	(5,033)	(6.63)	(2,587)	(2.50)	(1,013)	(0.83)
Utility Rate Escalation [5]	204	0.10	717	0.36	1,603	0.81	(2,877)	(2.78)	(2,587)	(2.50)	(2,087)	(2.01)
Tip Fee Escalation [6]	(913)	(0.46)	717	0.36	3,548	1.79	(3,441)	(3.32)	(2,587)	(2.50)	(1,104)	(1.07)
Poor Economic Conditions [7]	(2,666)	(1.84)	717	0.36	NA	NA	(4,488)	(5.92)	(2,587)	(2.50)	NA	NA
Strong Economic Conditions [8]	NA	NA	717	0.36	5,095	2.19	NA	NA	(2,587)	(2.50)	(212)	(0.17)

[1] All scenarios reflect Electric Energy Revenues based on 3.1 ¢/kWh
[2] Worst Case = 6.0%, Expected Case = 3.0%, Best Case = 1.0%
[3] Worst Case = 8.0%, Expected Case = 5.0%, Best Case = 3.5%
[4] Worst Case = 0.0%, Expected Case = 3.0%, Best Case = 4.5%
[5] Worst Case = 0.0%, Expected Case = 1.0%, Best Case = 2.5%
[6] Worst Case = 0.0%, Expected Case = 1.0%, Best Case = 2.5%
[7] High Inflation, High PV Rate, Low Waste Growth, High Utility Rates, High Tip Fees
[8] Low Inflation, Low PV Rate, High Waste Growth, Low Utility Rates, Low Tip Fees

The variable having the most significant financial impact on the operating results was "waste stream growth". The analysis reflects that with zero percent growth in the waste stream, the Large and Mid-Size plants may not be financially viable. Second, the exclusion of revenues from the sale of thermal energy has a significant impact on the operating results. Interestingly, varying the electric energy revenue rate has only limited impact on the net PV over the 20 year planning period.

5.3 Summary

Utilizing the base assumptions as outlined in the "Expected Case", the project operating results reflect a self-sustaining project at the Large Facility level with thermal revenues. As for the Mid-Size facility, the project operating results reflect a net loss both with and without thermal revenues. A summary of the net PV analysis on a per ton basis is provided below in Figures 5.1, 5.2, and 5.3.

Figure 5.1
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Projected 20-Year Profit/ton

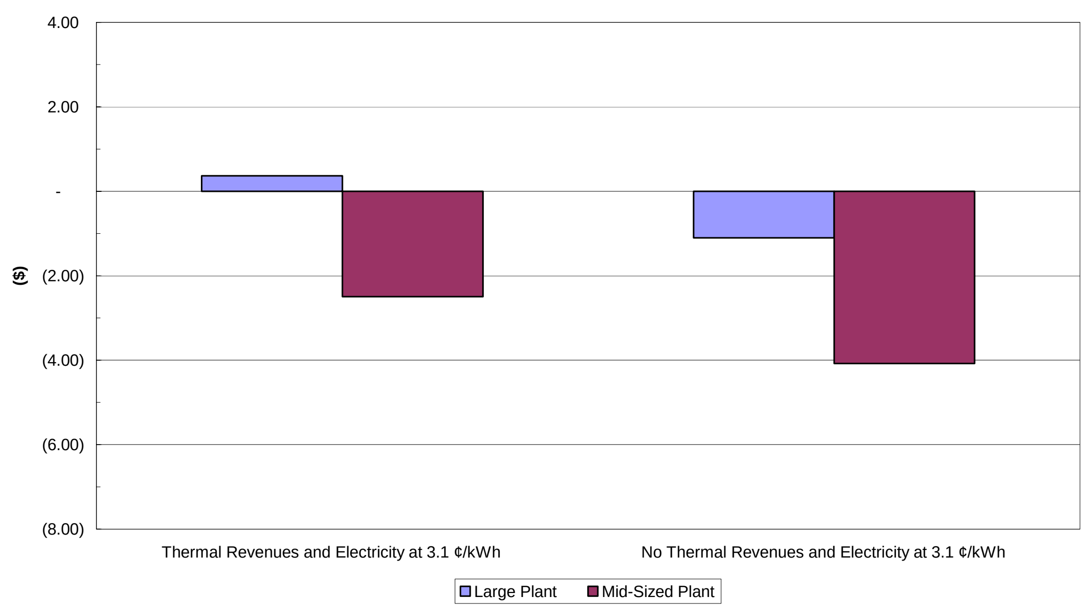


Figure 5.2
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Large AD Facility 20-Year Profit/ton

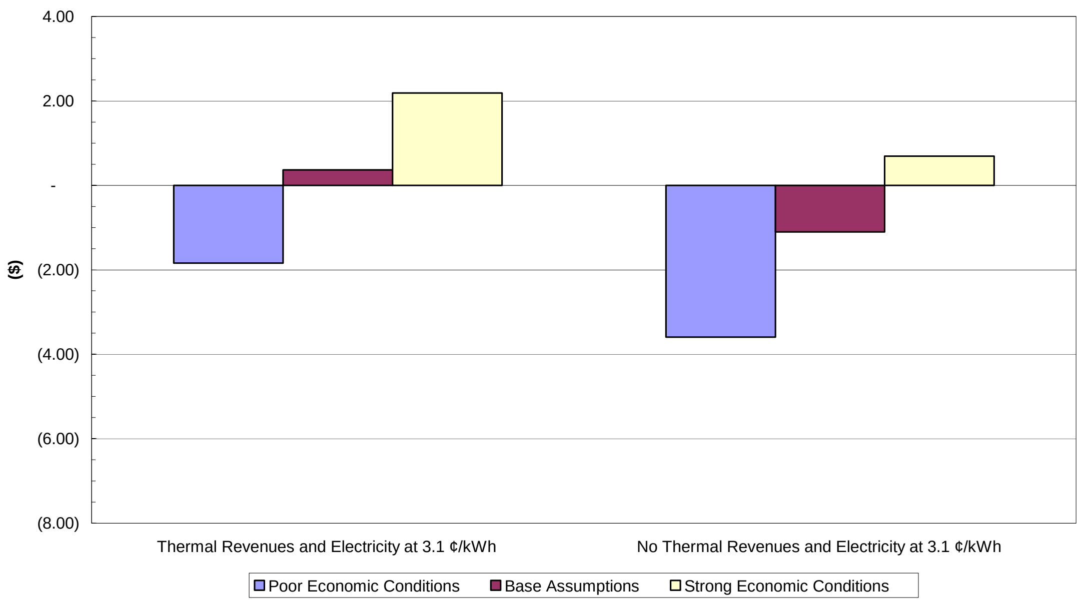
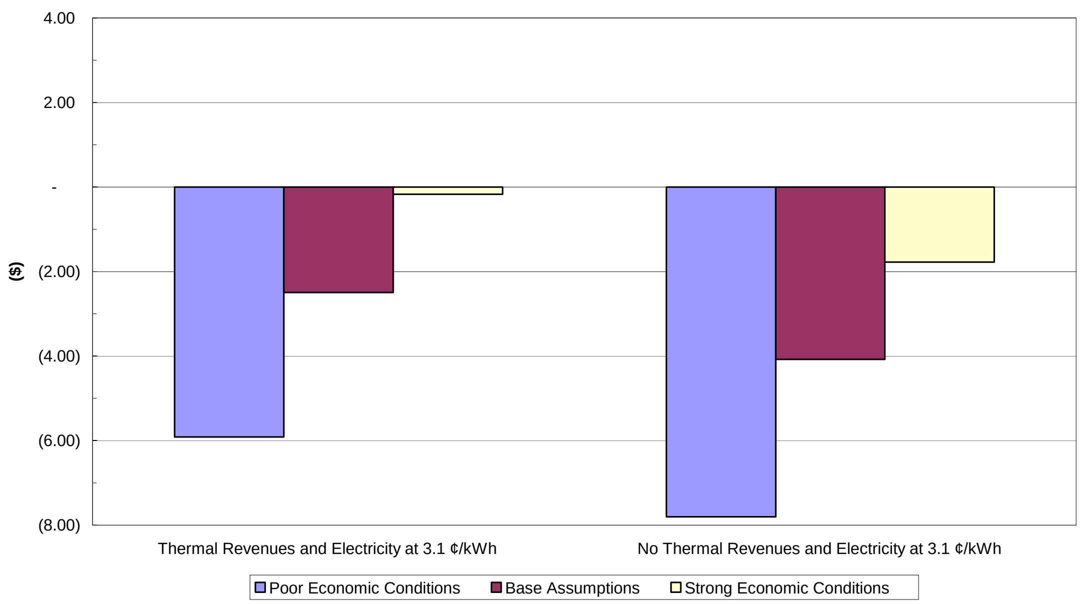


Figure 5.3
Bluestem Solid Waste Agency
Anaerobic Digestion Feasibility Analysis
Present Value of Mid-Sized Facility 20-Year Profit/ton



Because the project is likely to generate revenue through a per ton tip fee charge for materials received, one additional analysis was undertaken. The total revenues for the 20-year planning period were compared to the total annual costs. To generate adequate revenues with the expected case assumptions, a set of tip fees were calculated.

Overall, the average tip fees needed for a revenue-neutral project are characterized in Table 5.9.

Table 5.9
Revenue-Neutral Tip Fee
($/ton)

	Base Case	Mid-Level
With Thermal Energy	$14.43	$18.91
Without Thermal Energy	$16.73	$21.37

The tip fees ultimately selected must be at a level to economically attract the needed waste streams

Section 6
SITING AND INSTITUTIONAL ISSUES

6.1 Overview

Siting of a solid waste management facility in the Bluestem service area requires assessing which local and state regulations apply and how they apply to this potential project. Because AD facilities using MSW as feedstock do not presently operate in Iowa, there is no specific precedent serving either local or state governments surrounding the issue of siting and permitting of this type of solid waste facility.

This section of the report provides a preliminary overview of applicable state and local governmental siting and permit-related requirements.

6.2 Preferred Site

The Cedar Rapids Water Pollution Control Facilities (CRWPC) has approximately 30 to 40 acres of open space within its present facility footprint. Per discussions with CRWPC staff, it is the CRWPC's intent to use this area for expansion of its own facilities in the future. This expansion may address moving of the ash lagoons and/or expansion of its own anaerobic pre-treatment process which is used to manage biosolids. However, further discussions with CRWPC concerning the potential use of this area for an AD facility and sponsorship by the CRWPC are recommended. Figure 6.1 depicts the location of the CRWPC in the upper left-hand corner of the map.

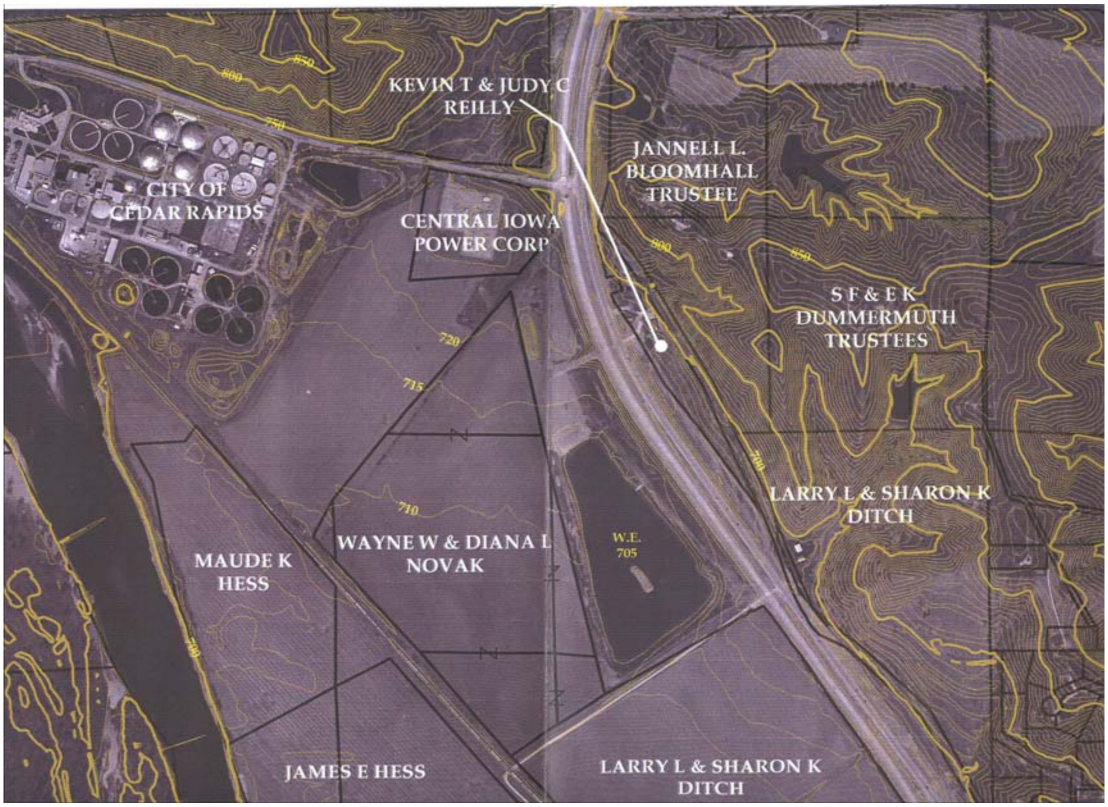


Figure 6.1

Critical to the financial viability of the AD project is access to markets for the co-products (e.g., digestate, biogas) of the AD process. Per discussions with CRWPC staff, it is estimated that CRWPC uses $5.5 to 6M of power annually. Total power costs represented approximately 15% of total operating costs in the 2003 calendar year. As for natural gas, the CRWPC facilities use biogas from their own treatment processes to displace their own natural gas needs from external sources. Locating an AD facility adjacent to the CRWPC facilities and generating electricity that could be used for CRWPC is an attractive option.

6.3 Local Zoning and Permitting

6.3.1 City of Cedar Rapids Overlay District

Per a review of applicable local zoning regulations and discussions with Bluestem staff, the City of Cedar Rapids' (City) Solid and Hazardous Waste Facility Overlay Zoning District (Overlay Zone) may be applicable. The Overlay Zone provides a set of conditions and requirements applicable to solid waste facilities. The Overlay Zone is to be used in conjunction with the existing Commercial Warehouse District, Restricted Industrial District, and General Industrial District. In addition to the underlying zoning district requirements for these three districts, an additional set of requirements and conditions addressing location and facility operations apply. The locational criteria include the following:

- at least 1/2 mile separation from a residential zoning district;
- at least 1/2 mile separation from property used for food processing related activities; and
- establish a buffer for visual screening from state or federal highways.

The operational requirements are drafted to promote use of best available technologies and minimize impacts on neighboring properties. Specific issues addressed include:

- odor control;
- debris control; and
- rodent and pest control.

Obtaining a legal opinion of the applicability of the Overlay District to an AD Facility is recommended. The definition of solid waste facility does not clearly encompass an AD facility. Solid waste facilities include "processing facilities" that manage solid waste for purposes of "volume reduction", including composting. Moreover, recycling processing facilities are defined as facilities that "extract useful materials" from the solid waste and activities are conducted "within a completely enclosed building". An AD facility processes materials for purposes of volume reduction and energy recovery using anaerobic digestion. Interestingly, facilities generating steam heat, power, or energy pursuant to a "franchise" granted by the City Council are exempt from the Overlay District requirements.

6.3.2 Linn County Exclusive Use District

Properties adjacent to the CRWPC facilities are actually located in Linn County (County). If other properties in this geographic area were considered, the County zoning regulations may be applicable. The County has codified a process for establishing an Exclusive Use District (District). The purpose of this District is to establish specific standards and ensure compatibility for adjacent uses for those uses that cannot be readily classified as agricultural, residential, business, professional office, or industrial uses.

Per review of the County ordinances, Exclusive Use Zone 1, Sanitary Landfill, has been established. Per review of the applicable uses for Exclusive Use Zone 1, it does not appear that an AD facility could be sited in this zone. It should be noted that compost and recycling facilities are listed as accessory uses in this zone. It is likely a new Exclusive Use Zone would need to be established separately for an AD Facility. The AD Facility would be handling solid waste, but not for purposes of final disposal and therefore does not appear to be a permitted use in Exclusive Use Zone 1.

Creating a new exclusive use zone for an AD facility requires formulating an amendment to the County zoning regulations. Then, the specific use to be permitted in the new Exclusive Use Zone must be approved by the Linn County Board of Supervisors. Specific regulatory requirements in Exclusive Use Zones may include:

- site design and locational standards;
- operational standards;

- bonding requirements; and
- reference to other applicable laws.

Per review of the Exclusive Use Zone 1, Sanitary Landfill Regulations, the specific requirements are comprehensive including such items as site development plan, hydrogeologic investigation, habitat inventory, and other specific operational and locational criteria. In addition, a comprehensive local siting approval process with extensive public input is required for uses within this District.

Overall, siting an AD Facility in the County under the Exclusive Use District provision appears to require substantial time and resources.

6.3.3 Linn County Air Quality Permitting

6.3.3.1 Overview

The Linn County Public Health Department, Air Quality Division, has been formally granted the authority by the U.S. Environmental Protection Agency and the Iowa Department of Natural Resources to implement and enforce the federal Clear Air Act within the County. As a result, the County has promulgated a set of provisions within the County Code of Ordinances addressing air quality issues applicable to a proposed AD facility.

The proposed AD facility is likely to require both construction and operating permits. Some exemptions from these permitting requirements are specified under County Ordinance #29-7-2002 including but not limited to:

- natural gas fuel-burning units for indirect heating with a capacity of less than 10 million BTU per hour input per combustion unit; and
- stationary internal combustion engines with a horsepower rating of less than 400 or a kilowatt output less than 300.

Based on preliminary review, it appears that neither one of these exceptions would be applicable. The first exemption appears to apply to combustion of natural gas for indirect heating purposes. It is likely the use of the biogas will be to generate electricity. Second, likely kilowatt output of the internal combustion engines used to generate electricity exceeds 300. The type of engines used to generate electricity would be similar that used at landfill gas-to-energy recovery facilities which individually have an output of 700 to 900 KW.

6.3.3.2 Construction Permit

Under Linn County Ordinance #29-7-2002, Section 10.5, the building or erecting of a machine or equipment which use may result in the emission of air contaminants must obtain a permit for authorities to install. This permit is requirement prior to the initiation of construction or installation of a stationary source. As a result, the development of an AD facility is likely to require an Authorization to Install Permit from the Linn County Public Health Department of Air Quality Division.

Information required as part of the application process includes the following:

1. Name, address, and location of firm.
2. Whether installation is new or an alteration of the existing device.
3. Identification of the emission point by number and its plant location.
4. Basic process or activity creating emission.
5. Basic principle of the control device.
6. Potential emission from source.
7. Type and quantity of the final emission after control.
8. Estimated equipment operation time in hours per week.
9. Engineering firm(s) responsible for design and installation.
10. Proposed installation completion date.
11. The name, address, and telephone number of the person submitting the application or, if such person is a legal entity, the name and address of the individual authorized to accept service of process on its behalf, and this person's signature.
12. One set of block diagrams and any other relevant information requested by the Air Pollution Control Officer.

The standards for issuing the Authorization to Install Permit include submittal of all required information, reasonable expectation that applicable emission standards are met, and projected emissions will not present attainment of air quality standards.

6.3.3.3 Operating Permit

Before the Authorization to Install Permit expiration date, an annual operating permit is likely needed to develop an AD facility. A written permit shall be obtained from the local Air Pollution Control Officer.

A permit to operate is not issued until the local Air Pollution Control Officer determines that the operating facility/equipment is operating within the emissions limits established and that operations of the facility will not prevent the attainment or maintenance of ambient air quality standards. A Permit to Operate is valid for one year after issued and therefore must be renewed on a yearly basis. Included in the Permit to Operate are specific sampling and testing requirements relative to air emissions.

6.3.3.4 Title V Operating Permits

An additional applicable permit is the Title V permit required under Title V of the Clean Air Act. The federal Environmental Protection Agency has delegated the authority to implement the Title V program in Iowa to the Iowa Department of Natural Resources. The role of the Linn County Public Health Department Air Quality Division is to facilitate the processing of the permit applications. The actual Title V permits are issued by the Iowa Department of Natural Resources.

The types of facilities required to obtain a Title V permit include the sources subject to the following:

- acid rain provisions;
- new source performance standards;
- natural emission standards for hazardous air pollutants; and
- air pollutants.

In addition, solid waste incinerators are required to obtain a Title V permit. Some sources of emissions also are required to obtain a Title V permit if they are considered a "major" source of emissions. A major source is one that exceeds the following thresholds:

- more than 100 tons/year of any air pollutant;
- more than 10 tons/year of any individual hazardous air pollutant; and
- more than 25 tons/year of all hazardous air pollutants combined.

A detailed review of Title V requirements is recommended upon moving forward with the development of the AD facility. A Title V permit may be necessary. More detailed calculations as related to likely emissions will be necessary to determine if specific thresholds are exceeded. Moreover, the AD facility owner/operator may choose to obtain a voluntary Title V operating permit.

6.4 State Permitting Requirements

This section provides a preliminary overview of applicable state permitting requirements for an AD facility. Issues addressed include:

- Wastewater Permit – Iowa Code 455B.305A;
- Comprehensive Planning – Iowa Code 455B.306; and
- Sanitary Disposal Project Permit – Iowa Administrative Code 567, Chapter 102 and 104.

6.4.1 Wastewater Permit

Filtrate will be produced as a co-product of the AD process. Filtrate results from separating the liquid fraction of the digestate from the fiber. This liquid fraction may be used in part as make-up water that can be recycled back into the AD process. A fraction of the filtrate will be considered excess process water and need to be appropriately disposed.

Iowa law requires facilities generating water that comes into contact with any waste product to be treated as process wastewater. Process wastewater generated from the AD facility would be categorized as a "new source" for the discharge of process wastewater. The excess process water will contain sulfides as a result of the scrubbing of the biogas prior to its use for fuel to generate electricity. With the CRWPC located adjacent to or near the potential AD facility location, the wastewater would be conveyed to the CRWPC for treatment and discharge by the CRWPC. The CRWPC is most likely capable of handling the AD excess process water without any pretreatment. CRWPC accepts and manages various industrial wastewaters without pretreatment. However, CRWPC and the AD facility operator would need to enter into an agreement for the acceptance and treatment of the excess process wastewater as a major contributing industry. The Iowa Department of Natural Resources would assist in facilitating the agreement and permitting process.

6.4.2 Comprehensive Planning

Under the authority of Iowa Code Section 455B.305, the Iowa Department of Natural Resources (IDNR) regulates the construction and operation of facilities that manage, process, and dispose of solid wastes. Iowa Code Section 455B.306 requires all cities and counties, as well as operators of sanitary disposal projects, to file a comprehensive plan. The plan must provide an explanation of how to achieve specified solid waste management goals and objectives. Bluestem has filed a comprehensive solid waste management plan with the IDNR. It is likely that if an AD facility was added to its integrated solid waste management system, an update to the comprehensive plan would be required. The addition of this component to their system will impact the overall material flows to the various integrated solid waste management components and impact long term objectives.

6.4.3 Sanitary Disposal Project Permit

A Sanitary Disposal Project, as defined in Iowa Code 455B.301, includes facilities used to "facilitate the final disposition of solid waste without creating a significant hazard to public health or safety". Moreover, Iowa Administrative Code Section 567 and Chapters 102 and 104 appear to be applicable to a proposed AD Facility. Chapter 102 requires securing of a sanitary disposal project permit prior to construction and operation of a sanitary disposal project. Because an AD facility is facilitating the management of solid waste, it appears securing a sanitary disposal project permit would be required. Moreover, Chapter 104, Sanitary Disposal Projects with Processing Facilities, may also be applicable. Chapter 104 is applicable to processing facilities with dumping or holding areas, hydropulping, slurring, storage, and sludge processing. An AD facility may include these components. In addition, the requirements of Chapter 102 include detailed engineering drawings for the equipment design and specific design and operational requirements.

6.5 Summary

Overall, the uniqueness of an AD Facility will likely require local and state regulators to revisit solid waste facility regulations. Additional legal review of these provisions is recommended prior to initiating the siting and permitting process.

Section 7
SYSTEM IMPACTS ANALYSIS

7.1 Overview

The purpose of this section of the report is to provide an overview of the impact on the Bluestem Integrated Solid Waste Management System (System) as a result of the addition of an AD facility component. The impacts may be measured in terms of quantities diverted and overall system costs.

7.2 Quantities Diverted

The materials targeted in the Base Case and Alternative Case facility scenarios are comprised of more than 90% organic industrial wastes and industrial sludges. Most of these materials, per the organic generator survey, are presently being composted by the Bluestem Solid Waste Agency (Agency) or land applied by the generator.

Per Section 3 of this report, 26,000 to 43,000 TPY of organic materials (i.e., OFMSW) were being landfilled by the Agency in FY2002. Most of these materials are not presently being source separated and would require incentives or mandates to be directed to the AD facility in a source separated form. These materials include yard waste, food waste, and non-recyclable paper. The facility scenarios modeled include approximately 3,300 tons per year of these types of materials. These quantities represent less than 1% of the total quantities of materials generated within the Bluestem service area.

Concerns have been raised by Agency staff as to the feasibility of continuing to accept and compost the increasing quantities of organic industrial waste and sludges. Limitations include both the physical site configuration of the compost facility and ability to market the compost by-product.

Adding the AD facility component to the Agency's System to manage the growing targeted waste stream will be beneficial. An AD facility component provides an increased level of flexibility to the Agency's System to promote long term capabilities to address changes in quantities and types of materials received.

7.3 System Costs

Section 5 includes the projected costs associated with the AD facility component. This analysis was conducted assuming the AD facility was developed as a stand-alone facility component by evaluating the net PV profit (loss) independent of the existing system.

The facility scenarios project diversion of a small quantity of additional materials from being landfilled. The facility scenarios focus on quantities of materials primarily being composted and land applied. Therefore, any changes in landfilling costs will be negligible. In addition, the facility scenarios target materials for collection assuming per ton disposal costs that are consistent with the existing tip fees for the individual materials (i.e., compost/sludges $15.00/ton; food waste $36.50/ton; and yard waste $15.00/ton). As a result, no additional costs are likely to be incurred for the collection and transportation of the materials to the AD facility, except for any incremental costs for transportation to the actual facility site.

The greatest impact on System costs would likely be at the existing composting facility. It is estimated that approximately 35,000 TPY less materials may be composted if the AD facility was developed. However, potential compost operations savings are likely to be offset with the anticipated growth in the industrial organic waste stream. The potential growth in the industrial organics is likely to ensure the compost facility is utilized to maximum capacity. As a result, long term compost facility operations savings are not anticipated, but some initial operations cost savings may accrue.

7.4 Summary

The AD Facility component offers flexibility to the Agency's System which is critical for long term program viability. The overall cost impacts of adding this component to the System are anticipated to be minimal, unless alternative facility scenarios are considered that target materials presently being landfilled.

Section 8
COMPARATIVE LIFE CYCLE ANALYSES OF MSW TECHNOLOGIES

8.1 Introduction

One of the key items related to the implementation of any technology is a life cycle assessment (LCA). An LCA is a technique where the inputs and outputs of an activity are systematically identified and quantified from the extraction of raw materials from the environment to their eventual assimilation back into the environment. These flows are then assessed in terms of their potential to contribute to specific environmental impacts.

The LCA concept dates from the 1960s, and early studies concentrated on the use of energy and materials in the manufacture of products. More recently, the focus of researchers has broadened to include a wide variety of environmental concerns including global warming, acidification, ozone depletion and eutrophication.

By taking the comprehensive life cycle approach, one can characterize the environmental advantages and disadvantages of alternatives by taking into account upstream and downstream consequences. The systems approach of LCA requires assessment of a process in terms of a 'functional unit' - generally a unit of waste handled for waste management operations.

With respect to the analysis for this report, the scope of the LCA is limited to the materials balance, the net energy balance, and the air emissions that are likely to be associated with an AD plant processing 69,000 tons/year of the organic fraction of MSW (OFMSW).

8.2 AD Life Cycle Analysis Overview

AD systems are net energy-*producing* processes, as compared for example to composting systems which are not energy consumers.

As outlined in Section 4, the co-products of the AD process include biogas and digestate. The digestate, in turn, may be separated into a compostable fiber and a liquid filtrate. The environmental benefits of the biogas are relatively straight forward. However, the relative benefits of the digestate products are complex to assess. The benefits are related to long-term soil structure and fertility as well as the substitution of soil conditioners and fertilizers.

8.3 Materials Balance

As noted above, this analysis is based on a conceptual AD facility capable of managing up to 69,000 tons/year of the OFMSW. Provided below is the overall materials balance for the conceptual AD facility.

Table 8.1
Materials Balance

Inputs	Unit	Annual	%
Feedstock	Tons	68,960	100%
Outputs	**Unit**	**Annual**	**%**
Methane	Tons	2,035	3.0%
CO2	Tons	3,088	4.5%
H2S	Tons	55	0.0%
Fiber	Tons	18,137	26.4%
Filtrate	Tons	44,422	64.4%
Total	Tons	67,736	100%

Recognizing the limited information available on its exact composition, the overall feedstock is calculated to have a TS concentration of around 24%, or approximately 120,000 pounds/day of solid matter. With an average VS concentration of around 87% of total solids (TS), it is estimated that the total daily volatile solids (VS) production is around 102,000 lb/day. It was also assumed that the AD facility would be capable of VS destruction potential of 50%, and that the average conversion into biogas was 5.1 ft^3/lb VS. Biogas production was estimated to approximately 400,000 ft^3/day. Further assuming that there are 600 BTU/ft^3 of biogas, the AD plant is capable of manufacturing 87,800 million BTU of methane annually. The sum of methane, CO2 and hydrogen sulfide (H2S), fiber, and filtrate compose the outputs.

8.4 Net Energy Balance

One of the most controversial issues related to energy production is the concept of a "net energy" balance.[1] Is more energy used to process the raw materials into useful primary and secondary co-products than is contained in the materials themselves? For this analysis, there are two basic outputs (methane and compost) and two basic inputs (electricity and thermal energy).

[1] Gushee, D. (1976). Energy Accounting as a Policy Analysis Tool. Congressional Research Service, Library of Congress, Washington, DC.

Table 8.2
Net Energy Balance

	Outputs M BTU/Yr	Inputs M BTU/Yr	Energy Balance (Outputs less Inputs) M BTU/Yr
Methane	87,800		
Soil Conditioner	9,700		
Electricity		4,600	
Thermal Energy		5,500	
Totals	97,500	10,100	87,400

The methane represents the gross amount of energy recovered from the anaerobic process. The energy used for manufacturing nitrogen fertilizer and phosphate is based on information provided by the Fertilizer Institute.[2] It requires approximately 22,200 BTU to produce a pound of nitrogen and 4,200 BTU for a pound of phosphate. More than 90% of the energy in the applied fertilizer is in the form of nitrogen, which is manufactured almost completely from natural gas. The energy embodied in phosphate includes 47% electricity, 27% diesel, and 26% natural gas. This calculation serves as a surrogate for energy value of the soil conditioner. Thus, the total energy outputs associated with the methane and soil conditioner are 97.5 M BTU/yr.

The required energy inputs are the electrical energy required for items such as pumps and the thermal energy required for digester heating. As detailed in other sections of this report, the digester is assumed to generate electricity as the end-use application of using the biogas. A conventional internal combustion cogeneration generator used for electricity production is assumed to have an average conversion efficiency of 35%, thus having a heat rate of 8,975 BTU/kWh. Assuming a 4.4 kWh/ton electrical requirement suggests that around 4.6 M BTU/year in parasitic electricity is required. Assuming an average temperature differential of 40°F/ton of feedstock is required to bring the material up to its desired temperature suggests that around 5.5 M BTU/year in parasitic heating is required. Thus, the total energy inputs for the hypothetical AD plant are estimated to be 10.1 M BTU/year.

Overall, the hypothetical AD plant is estimated to have a positive net energy balance of around 87,400 M BTU/yr as shown in Table 8-2.

[2] Reported in Shapouri, H., J. Duffield. and M. Graboski. (1995). Estimating the Net Energy Balance of Corn Ethanol. U.S. Department of Agriculture, Economic Research Service, Office of Energy. Agricultural Economic Report No. 721.

8.5 Air Emissions

The objective of this analysis is to present some estimates on primary air pollutants from an AD facility capable of treating up to 69,000 tons/year of the OFMSW generated within the Bluestem solid waste service area. The primary air pollutants from the use of methane to produce electrical power are carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NOx), and particulates.

The estimated annual air emissions from the hypothetical AD plant are provided in Table 2-3. There are three issues related to air emissions that are critical. First, the emission calculations for CO, NOx, and particulates. These pollutants are computed using the AP-42 emission factors published by the US Environmental Protection Agency (EPA) for natural gas. These factors predict emissions per million cubic feet of natural gas combusted, and the results listed in Table 2-3 use the projected methane content of the biogas.

Second, the AP-42 emission factors also provide a projection for SO_2, which is added to the amount of SO_2 contributed by combusting biogas containing H_2S. However, the H2S can be removed from the biogas prior to combustion using best available technology.

It was assumed that the biogas would contain 2500 parts/million (ppm) H_2S. Given the feedstock, this value could be as low as 1000 ppm or as high as 5000 ppm. Given the assumed SO_2 content from the AP-42 emission factors and the calculated H_2S concentration, the conceptual facility could potentially emit 3.83 tons of SO_2.

The third item is NOx emissions, of which 10.34 tons are projected as annual pollutants every year. This is the largest source of air emissions project for release by the facility.

A summary table is provided below characterizing the air emissions.

Table 8.3
AP-42 Method Air Emissions Estimator

Parameter	Quantity	Units
Biogas Produced	400,000	SCF/day
System Operation	365	days/year
Annual Biogas Production	146,000,000	SCF Year
Biogas Specific Volume	14.946	SCF/pound
Biogas Density	0.0669	pound/SCF
Annual CH_4 Production	2,035	tons/year
Annual CO_2 Production	3,088	tons/year
Biogas H_2S Content	2,500	ppmv
Annual H_2S Production	17.74	tons/year
SO_2 Emission from H_2S	1.78	pound/pound H_2S
Potential Annual SO_2 Production from H_2S	31.54	tons/year
H_2S Control	YES	
Control H_2S Content	300	ppmv
Control Annual SO_2 Production from H_2S	3.79	tons/year
SO_2 Emission Rate/AP-42	0.60	pound/million SCF
SO_2 Emitted Rate/AP-42	0.04	tons/year
Total Annual Control SO_2 Emitted	3.83	tons/year
Particulate Emission Rate/AP-42	13.70	pound/million SCF
Total Annual Particulate Emissions	1.00	tons/year
NOx Emission Rate/AP-42	140.00	pound/million SCF
Total Annual NOx Emissions	10.22	tons/year
CO Emission Rate/AP-42	35.00	pound/million SCF
Total Annual CO Emissions	2.55	tons/year

8.6 Global Warming and Greenhouse Gases

The Life Cycle Inventory (LCI) for GHG emissions characterizes the tons of GHG emitted/avoided per waste management method. The next step is to convert these quantities into a measure of the potential for global warming. The measure selected is metric tons of carbon equivalent (MTCE). This measure has been used by the Federal Environmental Protection Agency in its GHG modeling efforts.

Table 5-3 below depicts the conversion factors used to translate the LCI data into Impact Assessment measures. The listed coefficients are used to calculate the MTCE for each GHG. The source of these coefficients is the Intergovernmental Panel on Climate Change.

Table 8.4
GHG Effect Coefficients (100 Years)

Air Emission	Coefficient	Carbon Equivalent	MTCE/ (US) ton
CO_2 (fossil)	1	0.27	0.25
CH_4	21	5.73	5.19
CF_4	6,500	1,773	1,608
C_2F_6	9,200	2,509	2,276
N_2O	310	84.5	76.7

Source: IPCC, The Science of Climate Change 1996.

Carbon dioxide, methane (CH_4), chlorofluorocarbons, and nitrous oxide (N_2O) have varying potential to re-radiate heat. The coefficients above provide a means to uniformly measure this potential. Carbon dioxide is considered a reference gas for measurement of heat trapping potential. Using the coefficients provided above, the global warming potential (GWP) for these various concentrations of GHG can be calculated. The calculation of the GWP is based on understanding the fate of the emitted gas and the heating effect associated with the amount remaining in the atmosphere.

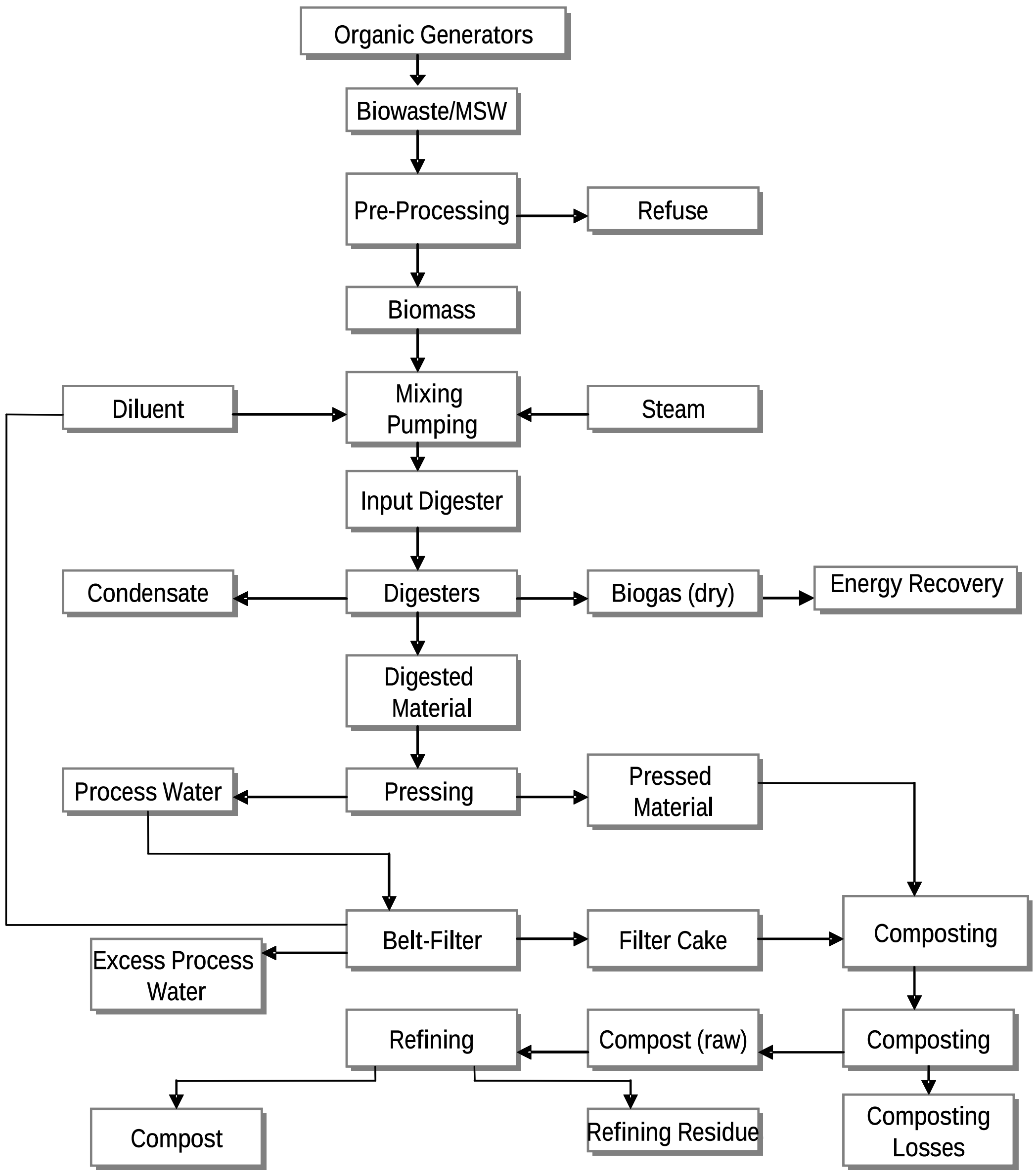
8.7 Emissions Per Ton Of MSW Managed

Translating the emissions emitted/precluded into comparable measures is critical to the LCA process. In addition, the system boundaries of the analysis must be established to characterize the scope of the comparison.

Our analysis takes into account the upstream activities that are precluded. For example, landfill gas to energy includes a calculation of the MTCE savings/offset associated with the displacement of other fossil fuels (i.e., coal, nuclear) with the use of methane to generate electricity. Therefore, a modified life cycle cost analysis can be developed.

The AD process can be characterized as including materials collection, processing, energy recovery, and reuse of compostables. The process flow diagram below represents the various steps typically associated with the AD process. Of the various technologies reviewed, this diagram is most similar to the Valorga dry, single-step AD process.

Process Flow Diagram [1]



[1] Represents a process similar to the Valorga International AD process.

We previously characterized the emissions from the process as primarily carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) and particulates. Moreover, we have projected the quantity of methane generated by the AD process that could be used as a fuel to generate electricity. To compare the AD process to the other MSW management methods, we propose to identify the MTCE per ton of MSW managed using similar activities supporting the calculations. Specifically, we have used Beck's previous work for the Minnesota Office of Environmental Assistance entitled "Assessment of the Effect of MSW Management on Resource Conservation and Greenhouse Gas Emissions". This study characterized the MTCE per ton of MSW managed by management method.

The feedstock as solid waste will be collected from various generators and transported to the AD Facility location. Some of these materials are likely to arrive in standard refuse collection vehicles and some via transport trailer. As a result, materials collection MTCE measures assumed as part of other methods (i.e., composting, landfilling) was used. The table below characterizes the net MTCE.

Table 8.5
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
Materials Collection	.006	-	-	-	.006

Source: Assessment of the Effect of MSW Management on Resource Conservation and Greenhouse Gas Emissions, R. W. Beck, 1999.

The AD process itself generates methane, CO_2, water and hydrogen sulfides. Table 8.3 included estimates of the tons/year of each of these materials. These estimates can be converted into MTCE per ton of MSW managed. Provided below is the calculated MTCE for the AD process, excluding the composting and energy recovery offsets.

Table 8.6
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
AD Process	.011	-	.15	-	.16

The other co-product, digestate, is then separated into fiber and water. The fiber can then be composted and reused as soil conditioner. Provided below are the composting MTCE values. The components of composting include equipment use, and decomposition emissions.

Table 8.7
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
Composting	.0023	-.083	.0001	.0001	-.080

Source: R. W. Beck, 1999.

Composting includes a credit for the "holding" of carbon in organic materials, as opposed to direct release into the environment.

The last component of the process to be included as part of the LCA is the use of the methane generated to produce electricity. The process of burning the fuel for energy recovery is similar to landfill gas to energy facility. The same type of combined heat and power equipment are used. Thus, for our purposes, we will utilize the offset for a landfill to energy recovery as a surrogate measure.

Table 8.8
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
Electricity Production	-.028	-	-.002	-	-.030

Source: R. W. Beck, 1999.

As a result, the total MTCE for the AD process as characterized above can be calculated by summing the various activities characterized above. Table 8.9 provides the overall estimate.

Table 8.9
Greenhouse Gas Emissions
MTCE/Tons of MSW Managed

	CO_2 (fossil)	CO_2 (sequestered)	CH_4	N_2O	Total per Ton
Collection	.006	-	-	-	.006
AD Process	.011	-	.15	-	.16
Composting	.0023	-.083	.0001	.0001	-.080
Electricity Production	-.028	-	-.002	-	-.030
Total	.045	-.083	.14	.0001	.056

Overall, the process has an impact on global warming comparable to landfilling with recovery of gas. The negative values represent MTCE precluded from being emitted and positive value represent emitted MTCE. The table below reflects the results for the various other solid waste management methods.

Table 8.10
Greenhouse Gas Emissions From MSW Management
Metric Tons Of Carbon Equivalent (Mtce) Per Ton Of MSW Managed

	CO2 (Fossil)	Co2 (Sequestered)	CH4	PFCS	N2O	Total Per Ton
Incineration	-0.078		-0.0094		0.010	-0.077
Landfilling, type A	0.0053	-0.10	0.29		0.0002	0.20
Landfilling, type B	0.0053	-0.10	0.15		0.0002	0.055
Landfilling, type C	-0.023	-0.10	0.13		0.0002	0.0053
Composting, Total Yard Waste	0.0023	-0.083	0.0001		0.00001	-0.080
Composting, MSW	0.0025	-0.12	0.0001		0.00001	-0.12
Recycling, Collection	0.014		0.0002		0.0008	0.015
Recycling, MRF	0.0072		0.0004		0.00004	0.0076
Recycling, PET	-0.47		0.001		0.0003	-0.47
Recycling, HDPE	-0.38		0.001		0.0003	-0.38
Recycling, OCC	0.052	-0.73	0.0001		0.0001	-0.68
Recycling, ONP	-0.21	-0.73	0.00001		0.0001	-0.94
Recycling, Steel/Tin Cans	-0.32		0.0001		-0.005	-0.32
Recycling, Aluminum	-3.5		-0.18	-0.70	-0.034	-4.4
Recycling, Glass	-0.056		-0.017		0.0001	-0.074
Source Reduction	-0.33		-0.014		-0.004	-0.35

Source: R. W. Beck, 1999.

As reflected above, the largest MTCE release on a per ton basis results from landfilling. The greatest per ton credits occur with recycling and source reduction. By material, the largest MTCE credits result from recycling aluminum, ONP, and OCC; and source reduction of office paper and plastics. The AD process offers GWP benefits by reducing the overall quantities of greenhouse gases that would otherwise be emitted if the methane from decomposition was not recovered.

POTENTIAL PROJECT FUNDING SOURCES

9.1 Introduction

The objective of this section is to identify potential funding sources for moving forward with the planning and development of an AD project. The potential funding sources are likely to be directly related to the overall anticipated environmental and economic benefits of the project. This is not intended to be an exhaustive survey of federal and state funding opportunities, but an initial review of potential opportunities.

9.2 U.S. Department of Energy

The U.S. Department of Energy (DOE) is the federal agency whose function is to work to assure clean, affordable, and dependable supplies of energy for our nation, now and in the future. Energy produced from biomass[1] is a component of its renewable energy portfolio.

9.2.1 Biomass Energy Program

To coordinate its biomass research and development, the DOE recently consolidated its biomass research programs and created a single, integrated Biomass and Biorefinery Systems R&D program. The intent is to improve the program's effectiveness by focusing resources on a limited and more coherent set of goals and objectives, reducing overhead expenses, exploiting synergies among similar activities, and eliminating the risk of possible duplication of effort. As a result of these organizational changes, the programs focus is on research pathways for converting biomass to useful output, including biorefinery processes. Integration of technologies by an industrial biorefinery for the processing of biomass materials and converting them into gaseous and liquid fuels provides identifiable benefits. Broadly defined, an AD system can meet the criteria established for an industrial biorefinery.

[1] The term 'biomass' means any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, wood and wood wastes and residues, aquatic plants, grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials.

Despite classifying the technology as a thermochemical instead of as a biological process, the technical committee that advises the Biomass Program on strategic direction recently recognized AD as an environmentally sound biobased fuel.[2]

The administration's Fiscal Year 2004 (FY04) budget proposal for the Biomass Program is $69.75 million, a 19% reduction as compared to FY03 levels.[3]

9.2.2 Federal Energy Management Program

The mission of DOE's Federal Energy Management Program (FEMP) is to reduce the cost of government by advancing energy efficiency, water conservation, use of renewable energy sources, and by helping agencies manage their utility costs. As one component of its activities, FEMP provides a wide range of resources to help agencies use private sector financing for their energy projects. FEMP helps to guide agencies through the process of financing and implementing projects using Utility Energy Service Contracts (UESCs) or DOE's Super Energy Savings Performance Contracts (Super ESPCs).

FEMP recently announced a new initiative called the Biomass and Alternate Methane Fuels (BAMF) Super ESPC that emphasizes the use of biomass and alternate methane fuels to reduce energy consumption, energy costs, or both at Federal facilities. Alternate methane fuels include landfill methane, wastewater treatment digester gas, and coalbed methane. The total maximum BAMF contract value is worth $200 million.[4]

Projects under the BAMF Super ESPC will reduce energy costs at Federal facilities by utilizing biomass and alternate methane fuels in a variety of applications such as steam boilers, hot-water heaters, engines, and vehicles. The biomass or alternate methane fuel resource could be owned by the Federal facility, the energy service company, or a third party, but end-use equipment must be located on Federal property.

Some projects will modify or replace existing equipment so that the facility can supplant or supplement their conventional fuel supply with a biomass or alternate methane fuel. Other projects may install equipment that uses these fuels to accomplish something altogether new at a Federal facility, such as on-site power generation. Although the primary component of any project under this Super ESPC must feature the use of a biomass or alternate methane fuel, all projects are also expected to employ a variety of traditional conservation measures, such as retrofits to lighting, motors, and HVAC systems to reduce energy costs.

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[2] The Biomass Research and Development Technical Advisory Committee (2002). Roadmap for Bioenergy and Biobased Products in the United States. Available at: http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf

[3] The entire DOE FY04 budget can be accessed at http://www.mbe.doe.gov/budget/04budget/

[4] The BAMF program can be accessed at: http://www.eere.energy.gov/femp/financing/superespcs_biomass.cfm

9.3 U.S. Environmental Protection Agency (EPA)

9.3.1 Innovations Work Group (IWG)[5]

The IWG accepts creative pilot proposals that promote energy recovery, waste minimization, recycling, environmental protection through land revitalization, and retail partnerships. Through an EPA funding allocation process, a limited amount of funding is available to support innovative ideas in the EPA regions.

Proposals for funding under this program can be submitted by EPA Headquarters or Regional offices. If other public authorities (Federal, State, interstate, intrastate, and local); public agencies and institutions; nonprofit private organizations, agencies, and institutions; academia; and federally recognized Native American Tribes are interested in participating in this initiative they must approach an IWG member or another EPA Regional or Headquarters' employee to discuss their idea. Since this is an internal allocation of funds, an EPA representative must sponsor or "advocate" for a proposal.

All funds allocated under this program can be placed into Interagency Agreements (IAGs), contracts, cooperative agreements, or grants depending upon the principal purpose of the transaction.

The first round of pilot proposals was selected in June, 2002 and totaled $524,850.

Below are the six criteria used to evaluate the proposals:

- Addresses a critical challenge or unmet need;
- Fosters innovative approaches to environmental challenges;
- Can measure and evaluate success;
- Builds and strengthens partnerships with state, tribal and local governments or interested public;
- Can be replicated; and
- Leads to short term results.

Through this program, a biomass energy conversion study was funded last year in the amount of $51,736 in Iowa. The partners were the Biomass Energy Conversion (BECON) Facility and the Iowa Energy Center/Iowa State University. BECON will investigate the feasibility of establishing new, bio-based plastic manufacturing processes. BECON represents a multi-million dollar investment by the Iowa Energy Center to produce value-added products from farm crops and wastes. The goal is to minimize current petroleum-based plastic production with products made from cleaner, biological sources such as paper, food wastes, scrap wood, yard wastes, etc.

In addition, the IWG funded a $45,000 Food Waste Composting project in Colorado. The project partners were the University of Colorado at Boulder and the City of Boulder Office of Environmental Affairs. The project's objective was to determine the cost-effectiveness and practicality of on-site, in-vessel composting technology at

[5] IWG program information can be accessed at: http://www.epa.gov/oswer/IwgPilotInitiative.htm

the university. The City of Boulder is interested in testing the in-vessel composting technology as a potential component to its planned municipal composting operation. The pilot program has potential to lead to a large-scale municipal food collection program that could set a precedent for other urban food waste diversion programs.

The IWG usually has two review panels each fiscal year - one in the Spring and one in the Fall. Spring proposals are typically due in April, and Fall proposals are typically due in November or December.

9.3.2 National Center for Environmental Research (NCER)[6]

The National Center for Environmental Research (NCER) is one of five research organizations that comprise EPA's Office of Research and Development (ORD). NCER's mission is to support high-quality research by the nation's leading scientists that will improve the scientific basis for decisions on national environmental issues and help EPA achieve its goals.

NCER's Science to Achieve Results (STAR) program funds research grants and graduate fellowships in numerous environmental science and engineering disciplines through a competitive solicitation process and independent peer review. Some examples of research projects funded in recent years include:

- Innovative Technology for Efficient Utilization of Municipal Solid Waste;
- Innovative Technology for Municipal Solid Waste Disposal and Landfill Mining;
- Biodetoxification of Mixed Solid and Hazardous Wastes by Staged Anaerobic Fermentation Conducted at Separate Redox and pH Environments;
- Technology for a Sustainable Environment: Computer-Aided Hybrid Models for Environmental and Economic Life-Cycle Assessment; and
- Compliance and Beyond: Strategic Government-Industry Interactions in Environmental Policy and Performance.

STAR has four formal solicitation periods each year during January, April, August, and October and awards approximately $100 million per year.

9.3.3 EPA Region 7 - Serving Iowa, Kansas, Missouri, Nebraska and 9 Tribal Nations[7]

Region 7 of the EPA, which serves Iowa, has a webpage dedicated to various resources for Community Based Environmental Protection (CBEP) programs and offers a link to a grant writing tutorial. This website also has a link to a grant matrix which is a summary of community grant programs offered in Region 7. One of the grants listed is the Solid Waste Disposal Act grant. Its purpose is to support demonstration projects that promote effective solid waste management through source

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[6] NCER program information can be accessed at: http://es.epa.gov/ncer/about/
[7] EPA Region 7 information can be accessed at: http://www.epa.gov/Region7/citizens/cbep/resources.htm

reduction, reuse and recycling. Eligible recipients include non-profit organizations, tribal governments, state, city, county, or local governmental agencies. Although no reported funding has been available in recent years, we recommend that Bluestem check with the Region 7 contact person for possible grant opportunities in the future.

9.3.4 Other EPA Resources

Other EPA links to funding opportunities include:

- Environmental Finance Program: http://www.epa.gov/efinpage/efp.htm
- Catalog of Domestic Assistance: http://www.cfda.gov/

9.4 Iowa Department of Natural Resources: Energy and Waste Management Bureau[8]

The Iowa Department of Natural Resources Energy and Waste Management Bureau offers two relevant financial assistance programs.

9.4.1 Solid Waste Alternatives Program (SWAP)[9]

The Iowa DNR's Land Quality and Waste Management Assistance Division has a grant and loan program to "encourage implementation of innovative waste reduction and recycling techniques, develop markets for recyclable materials and products, and encourage the adoption of the best waste management practices". The SWAP grant is designed to reduce the amount of solid waste generated and landfilled in Iowa and to alter people's attitudes about generating, managing and disposing of solid waste. Financial assistance aids in implementing various pollution prevention and solid waste management projects in three targeted areas:

- Best Practices - Assists in implementing practices and programs that will move Iowa toward long-term pollution prevention, waste reduction and recycling sustainability.
- Education - Facilitates the coordination of consistent statewide pollution prevention, waste reduction, and recycling messages to ensure ongoing support of these activities.
- Market Development - Develops a demand for value-added recyclables sufficient to provide increased and stable commodity market prices.

Projects involving regionalization (those including two or more units of local government or public or private groups) are preferred. The cooperative delivery of a

[8] The Iowa DNR Energy & Waste Management Bureau can be accessed at: http://www.state.ia.us/dnr/energy/MAIN/renewable/incentives.html#AllTechnbologies

[9] Iowa DNR grant information can be accessed at: http://www.state.ia.us/dnr/organiza/wmad/wmabureau/solidwaste/swap/index.html

project may significantly enhance the operational efficiency, materials diversion, materials market value or other aspects of the project.

9.4.2 Iowa Energy Bank Program

The Iowa Energy Bank is an energy management program using energy cost savings to repay financing for energy management improvements. The program targets public and non-profit facilities such as public schools, hospitals, private colleges, private schools, and local governments. The Iowa Energy Bank is expected to facilitate more than $250 million in improvements using private funds in combination with minimal state and federal support.

The Iowa Energy Bank starts with an initial energy audit and DNR staff help manage the energy efficiency improvements and financing process. Solutions are customized to meet the specific needs of an organization, assure high technical quality and provide potential cost savings. Financing is provided through area lending institutions that create budget-neutral, affordable financial packages.

9.5 The Iowa Energy Center[10]

The Iowa Energy Center (Energy Center), located at Iowa State University, provides in-house energy research and education programs and sponsors energy projects.

9.5.1 Grants for Energy Efficiency and Renewable Energy

The Energy Center awards grants to Iowa-based, nonprofit groups to conduct energy-related research, demonstration and education projects. These projects, which range in size and complexity, are conducted throughout the state, including Iowa's three major universities, several community colleges and at nonprofit energy organizations and community-based educational groups. Grants are awarded on a competitive basis through periodic Requests for Proposals (RFPs).

Examples of projects funded by The Iowa Energy Center include:

- Biohydrogen Production from Renewable Organic Wastes - Iowa State University;
- Supercritical Water Gasification of Biomass - The University of Iowa; and
- Water and Wastewater Treatment Technology Tool for Determining Energy and Treatment Costs in Iowa - Iowa Association of Municipal Utilities.

9.5.2 Alternate Energy Revolving Loan Program[11]

The Iowa Energy Center also administers a loan program for alternative energy projects that is funded by the state’s investor-owned utilities. The program offers

[10] The Iowa Energy Center: http://www.energy.iastate.edu/funding/gp-index.html
[11] Alternate Energy Revolving Loan Program: http://www.energy.iastate.edu/funding/aerlp-index.html

zero-percent interest loans for up to one half of the project cost, up to a maximum of $250,000. Residential, commercial and industrial sectors are eligible. Funding is awarded during a specific grant cycle according to the following percentages: solar - 5 percent of available funds; methane - 30 percent; biomass - 20 percent; small wind (<10kW) - 10 percent; large wind (>10kW) - 20 percent; and hydropower - 15 percent.

9.6 State of Iowa Incentives

In addition to the above programs, the state of Iowa offers two applicable tax exemptions that may provide incentives for developing AD projects.

9.6.1 Methane Gas Conversion Property Tax Exemption

Iowa Code 427.1(29) exempts personal property, real property, and improvements to real property used to collect and convert methane gas to energy from the state property tax. If a facility on the property also uses another fuel, the exemption shall apply to that portion of the value of such property, which equals the ratio that its use of methane gas bears to total fuel consumed. Applications shall be filed with the assessing authority not later than February 1 of each year for which the exemption is requested on forms provided by the Department of Revenue and Finance.

9.6.2 Methane Energy Replacement Generation Tax Exemption

Iowa Code 437A.6 exempts electricity generated by methane gas conversion property from the replacement generation tax, which is six hundredths of a cent per kilowatt-hour.

9.7 Summary

Based on the review of the funding sources outlined above, the likelihood of federal support for an AD project from existing appropriations is limited. For example, the DOE FY04 Biomass Program budget has a proposed reduction of almost 19% compared to its FY03 budget. The FEMP BAMF Program may be a potential funding source, especially if Bluestem could partner with a federal agency on the project. Other options to consider would be to expand the activities of FEMP to allow state and local agencies the opportunity to participate. One other option to consider is engaging Linn County's Congressional delegation for a direct earmark to the project.

As for the EPA, both the IWG and NCER are potential funding sources. Additional discussions are recommended with representatives of both programs to determine potential interest in AD projects. For funding directly related to AD facility design, construction, and operation, the Project Team recommends further investigation of the Iowa Department of Natural Resources’ Energy and Waste Management Bureau's SWAP Program and the Iowa Energy Center's Alternate Energy Revolving Loan Program.

Section 10
FINDINGS

Based on the information gathered and analysis conducted, Beck characterizes the following findings:

10.1 Technology

- Anaerobic digestion is the decomposition of organic matter without oxygen resulting in volume reduction and the generation of biogas (i.e., methane) and digestate (i.e., fiber and water).
- Anaerobic digestion is being effectively used in several locations throughout Europe to manage the organic fraction of municipal solid waste (OFMSW), yard waste, food wastes, organic industrial wastes, sludges, and manures.
- Wet digestion (15% or less total solids) is generally used with co-digestion of organic materials and liquid substrates such as manures/biosolids.
- Dry digestion (15% to 35% total solids) is generally used for the digestion of the OFMSW.

10.2 Feedstock

- A written survey of commercial/industrial/institutional organic waste generators in the Bluestem service area reflected that most of the organics generated are being diverted from disposal.
- Nearly 15% to 25% of the solid waste being disposed can be characterized as organic wastes and may be available for use as a feedstock. However, most of this fraction of the waste stream is not presently being source separated and would need to be directed to an AD facility using financial incentives or regulatory changes.
- Two potential sized AD facilities – 69,000 TPY and 36,000 TPY should be considered for future analysis.

10.3 Costs

- Capital costs for the large AD facility are estimated to range from $12.8 to $14.2 million.
- Capital costs for the mid-sized facility are estimated to range from $9.0 to $9.4 million.

- The net present value (PV) over a 20 year planning period calculating the PV of the revenues less the PV of the operating and amortized costs results in a positive cash flow for a Large AD facility. This assumes revenues from both electric power and thermal energy sales.
- The net present value over a 20 year planning period results in a negative cash flow for a Large AD facility, assuming no thermal energy revenues. Similarly, the Mid-Sized Facility offered a negative cash flow with and without thermal energy revenues.
- Growth in the waste stream over the 20 year planning horizon has the most significant impact of any variables analyzed as part of a sensitivity analysis.
- Varying the electric energy revenue rate has only a limited impact on the net PV over a 20 year planning period.
- An average tip fee of $14.43 - $16.73 per ton for the Large AD Facility scenario offers an opportunity for project development with adequate revenues to cover projected expenses over a 20 year planning horizon.
- An average tip fee of $18.91 to $21.37 per ton for the Mid-Sized AD Facility scenario offers an opportunity for project development with adequate revenues to cover projected expenses over a 20 year planning horizon.

10.4 System Impacts

- Development of the Large AD Facility offers the potential to produce a quantity of biogas composed of 65% to 75% methane adequate to generate more than 1 MW of electrical power.
- Development of the Large AD Facility offers nearly a 75% reduction in the total volume of materials with the potential for the reuse of the residual fiber as compost.
- The addition of an AD Facility to Bluestem's integrated solid waste management system provides an increased level of flexibility to manage future changes in the quantities and types of materials received.
- The addition of an AD Facility would have minimal impact on system collection costs but may increase compost facility costs because of additional compostable materials as a co-product of the AD process.
- The AD Facility is a net energy producer and offers definitive global warming benefits through the capture and reuse of the methane (i.e., greenhouse gas) that would otherwise be generated as part of the decomposition of the available feedstock.

Anaerobic Digestion (AD): The decomposition of organic matter without oxygen. This process decomposes biodegradable material while converting it into biogas (consisting of primarily methane and carbon dioxide) and digestate.

Biogas: The methane and carbon dioxide produced as a result of anaerobic digestion or degradation. The gas can be used for producing heat and electricity, or successfully compressed for use as an alternative transport fuel.

Biomass: Any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, wood and wood wastes and residues, aquatic plants, grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials.

Biowaste: Also known as “green waste”, it is the organic fraction of the waste stream.

Centralized Separation: Separating organics from the MSW stream at a central facility after collection (not at the source).

Continuously Stirred Tank Reactor (CSTR): A complete mix tank digester that operates at a steady rate with continuous flow of reactants and products. A CSTR creates uniform composition throughout the reactor.

Digestate: A slurry containing undigested solids, cell-mass, soluble nutrients, other inert materials, and water. High quality digestate (i.e., from Centralized Separation) is commonly used a soil conditioner. Lesser quality digestate is commonly used for landfill cover or land remediation projects.

Grey Waste: The residue that remains after source separating the organic fraction from MSW. Generally, grey waste has a lower biogas potential because the easily digestible fraction has been removed.

Hydraulic Retention Time (HRT): The average time a particle resides in a bioreactor (or other device) through which a liquid medium continuously flows.

High-Solids Anaerobic Digestion (HSAD): Commonly referred to as a “dry” AD system, in which total solids (TS) concentration is between 15% and 35%.

Mechanical Biological Treatment (MBT): The combination of centralized separation and biological treatment (aerobic composting, AD, or both processes in series).

Mesophilic Digestion: The digester is heated to 30-35°C and the feedstock remains in the digester typically for 15 to 30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process, but gas production is generally less and larger digestion tanks are required.

Organic fraction of MSW (OFMSW): The portion of the municipal solid waste (MSW) stream that contains organic materials.

Organic industrial wastes (OIW): Organic wastes that are generated by the industrial, commercial, or institutional sector, as opposed to residential organic waste.

Source Separation: Separating organics from the MSW stream at the source (i.e., at the home or business) before collection.

Thermophilic Digestion: The digester is heated to at least 55°C and the residence time is typically 12 to 14 days. Thermophilic digestion systems typically offer higher methane production, faster throughput, and better pathogen control, but require more capital intensive technology, greater energy input, and a higher degree of operation and monitoring.

Total Kjeldahl nitrogen (TKN): The sum of organic nitrogen and ammonia in a water body. Measured in milligrams per liter (mg/L). High measurements of TKN typically results from sewage and manure discharges to water bodies.

Total Solids (TS): Dissolved and suspended solids in water. Higher concentrations of suspended solids can serve as carriers of toxics, which readily cling to suspended particles. Sources of total solids include industrial discharges, sewage, fertilizers, road runoff, and soil erosion. Total solids are measured in milligrams per liter (mg/L).

Volatile Solids (VS): The organic fraction of Total Solids (TS), of which a portion is converted into biogas.

Wet AD System: AD system in which total solids (TS) concentration is generally less than 15%.

Appendix A

Anaerobic Digestion Facility Survey

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name			
Street			
Town			
Country			
Telefone			
Fax :			
E-mail :			
Contact Person			
Name			
Function			
Status	☐ Public ☐ Private ☐ Other : ……	☐ Public ☐ Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

……	Energyproduction
……	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
……	Rentability as compared to other Processes
……	Other

Surface required for treatment

……………m2

Construction time

Start of construction:..................

Start-up of plant:........................

Remarks

Description of the Main Substrates

SUBSTRAT	**Substrate n°1**	**Substrate n°2**	**Substrate n°3**	**Substrate n°4**	**Average Composition**
Characterization					
Origin	…………………	…………………	…………………	…………………	…………………
Type	…………………	…………………	…………………	…………………	…………………
Amount per Year (in tons or m3)	…………………	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	☐	☐	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
VS-content	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes/No**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	☐ Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	☐ Biological treatment
☐ Other :…………………….	☐ Other:………………	☐ Other:………………
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	…….…. t or…….. …….…. m^3	…….…. t or …….…. m^3	…….…. t or …….…. m^3	…….…. t or …….…. m^3
Is the amount estimated or measured?	**Yes/No**	**Yes/No**	**Yes/No**	**Yes/No**
Composition				
DM-content	…….…. % or…….. …….…. g/l	…….…. % or …….…. g/l	…….…. % or…….…. g/l	…….…. % or …….…. g/l
VS-content	…….…. % or …….…. g/l	…….…. % or …….…. g/l	…….…. % or …….…. g/l	…….…. % or …….…. g/l
COD	…….…. mg/l	…….…. mg/l	…….…. g/l	…….…. g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Lanfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:...............................	☐ ……………..	☐ ……………..	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	☐.....................	☐.....................	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digestor(s)**
Dimensioning	
Number of digestors	…………………
Volume of each digestor	……/………/…… m^3
Input Material	
Consistency	☐ Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	……………. mm
Type of digester	
Operation	Batch / **Continuous**
Digestion temperature	………………… °C
Make & Type of digester	…………….
Provider	…………………
Internal or external heat exchanger	yes/no
Mixing	
Mixing with compressed biogas	☐
Mechnaical Stirrer	☐
Hydraulic stirring	☐
Other	☐ …………….........
None	☐

Remarks

Double Stage Digestion

Digestion	First Stage Type of Digester 1	Intermediate Treatment (Please describe)	Second Stage Type of Digester 2
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Yearly Energy Balance

Gros Biogas-Production:……………………….m3 Excess Biogas (Flare):..................... m3

Raw Biogas

- Is the gas composition analyzed: Yes / No
  if yes::
  - CH_4 : ……….. % vol
  - CO_2 : ……….. % vol
  - H_2S : ……….. ppm
  - Other : ……….. ……….. ppm
- Is there a gas container? : **Yes / No**
  if yes, give size :……………….m3
  Type :
  - ☐ Gas balloon
  - ☐ Steel bell
  - ☐ Other : ………..

Biogas Upgrading

- Is the biogas upgraded? : **Yes / No**
  if yes: Gas composition after treatment
  - CH_4 : ……….. % vol
  - CO_2 : ……….. % vol
  - H_2S : ………... ppm
  - Other : ……….. ……….. ppm

Type of gas upgrading :

- ☐ Washer: **W**asser / **org.** Lösungsmittel
- ☐ Acitvated carbon
- ☐ Membrane
- ☐ Other

Electricity Production **Yes/No**

- Type of electricity production :
  - ☐ CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell
- Total installed power : .... kWel.
- Number of generators : ....
- **Gross electricity production :** …………….. kWh
- Utilization of produced electricity :
  - Sale to third party …………….. kWh
  - Self-consumption …………….. kWh

Heat Production **Yes/No**

- Type of heat production :
  - ☐ Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - ☐ Heat from CHP
  - ☐ Other : ……………………
- Total installed power : .... kWth.
- **Gross heat production :** …………….. kWh
- Utilization of produced heat :
  - Sale to third party …………….. kWh
  - Self-consumption …………….. kWh

Other Utilization of the Biogas **Yes/No**

- ☐ N Injection into the gas grid
- ☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilzation of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utlization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax monney	....
Other:..........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Appendix B

Completed Surveys from Anaerobic Digestion Facilities

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Abfallbeseitigungs Gmbh	Owner	Linde BRV
Street	Zur Maibolte 200		Rue du Verger 11
Town	D-32657 Jungo		CH-2014 Bôle
Country	BRD		Switzerland
Telefone	052 61 948 716		0041 32 843 04 50
Fax :	052 61 948 725		
E-mail :	abg-lippe@t-online.de		brvinfo@bluewin.ch
Contact Person			
Name	Herr Frohmann		H. Sickinger
Function	Procurator		
Status	X Public ☐ Private ☐ Other : ……	☐ Public ☐ Private ☐ Other : ……	

Various Information

Reasons for the Choice of the System

X	Energy Production
	Production of Compost
X	Reduction of Waste Volume or Weight
X	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

50'000 m2

Construction time

Start of construction: 1998

Start-up of plant: 2000

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	?	?	…………………	…………………	…………………
Type	Bio waste	Garden waste	…………………	…………………	…………………
Amount per Year (in tons or m3)	34'000 t	6'000 t	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	☐	☐	☐
Aerobic pre-treatment	X	X	☐	☐	☐
Hygienization	X	X	☐	☐	☐
Dehydration	X	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	45 % od ……..… g/l	60 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
VS-content	54 % od ……..… g/l	65 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	**Upgrading Solid Phase**	**Upgrading Liquid Phase**
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other: Steaming
☐ None	☐ None	☐ None

	Digestate	**Solid Phase**	**Liquid Phase**	**Remaining Fraction**
Quantity				
Quantity per year	18'000 t or…….... ……..… m^3	4'500 t or ……..… m^3	13'500 t or ……..… m^3	……..… t or ……..… m^3
Is the amount estimated or measured?	**No**	**No**	**Yes/No**	**Yes/No**
Composition				
DM-content	44 % or…….. ……..… g/l	55 % or ……..… g/l	20 % or……..… g/l	……..… % or ……..… g/l
VS-content	52 % or ……..… g/l	55 % or ……..… g/l	35 % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:...............................	X Pressing/Composting	X Composting	X Composting	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	X BioABfVo	X BioABfVo	X BioABfVo	☐.....................
a label product	X RAL Gütezeichen 256/1	X RAL Gütezeichen 256/1	X RAL Gütezeichen 256/1	☐.....................
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	3
Volume of each digester	850 / 850 / 850 m^3
Input Material	
Consistency	☒ Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	30 mm
Type of digester	
Operation	**Continuous**
Digestion temperature	50 °C
Make & Type of digester	Stahlbeton
Provider	Linde BRV
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	☐
Hydraulic stirring	☐
Other	X Paddel (langsam laufend)
None	☐

Remarks

Double Stage Digestion

Digestion	First Stage Type of Digester 1	Intermediate Treatment (Please describe)	Second Stage Type of Digester 2
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /Continuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 3'800'000 Nm3 Nicht verwendete Biogasmenge (Fackel):.................. m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a / **N**ein

falls ja::

CH_4 :	63	% vol
CO_2 :	………..	% vol
H_2S :	………..	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : **Ja**

falls ja, Speichergrösse : 300 m3

Typ : X Foliengasspeicher
☐ Wassertassengasometer
☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	63	% vol
CO_2 :	………..	% vol
H_2S :	………...	ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
X Aktivkohle
☐ Membran
X Andere: Entschwefelung

Electricity Production **Yes/No**

- Type of electricity production :

X CHP
☐ Gas turbine
☐ Steam turbine
☐ Fuel Cell

- Total installed power : 936 kWel.

- Number of generators : 2

- Gross electricity production : 6'000'000 kWh

- Utilization of produced electricity :

Sale to third party	6'000'000	kWh
Self-consumption	……………..	kWh

Heat Production **Yes/No**

- Type of heat production :

☐ Boiler: Steam/Heat (siehe Original)
☐ Air heat exchanger
☐ Heat from CHP
☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : 11'000'000 kWh

- Utilization of produced heat :

Sale to third party	…………...	kWh
Self-consumption	8'000'000	kWh

Other Utilization of the Biogas **Yes**

☐ N Injection into the gas grid
☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (DM)
Gross Investment Cost Fermentation + Composting	32 Mio.
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (€)
Electricity	0.0975 / kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	- 8 /t or /M3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (€)
Operation and maintenance; if possible: - labor cost	
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (€)
Per Ton	90/t

Success and failures

Alfred Müller

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Alfred Müller AG	Alfred Müller AG	Linde BRV
Street	Neuhofstrasse 10	Blickensdorfer Allmend	Rue du Verger 11
Town	CH-6340 Baar	CH-6340 Baar	CH-2014 Bôle
Country	CH-6340 Baar	CH-6340 Baar	Switzerland
Telefone	0041 41 767 02 02	0041 41 767 07 47	0041 32 843 04 50
Fax :	0041 41 767 02 00	0041 41 767 52 02	0041 32 843 04 51
E-mail :	mail@alfred-mueller.ch	mail@alfred-mueller.ch	brvinfo@bluewin.ch
Contact Person			
Name	Heinz Brotschi	René Büttikofer	H. Sickinger
Function	Department head	Manager	
Status	☐ Public X Private ☐ Other : ……	☐ Public X Private ☐ Other : ……	

Various Information

Reasons for the Choice of the System

	Energy Production
	Production of Compost
	Reduction of Waste Volume or Weight
	Reduction of the Organic Fraction
	Marketing/PR
	Subsidies as a Driver
X	Rentability as compared to other Processes
	Other

Surface required for treatment

10'000 m2

Construction time

Start of construction: 1993

Start-up of plant: 1994/1995

Remarks

Description of the Main Substrates

SUBSTRAT	**Substrate n°1**	**Substrate n°2**	**Substrate n°3**	**Substrate n°4**	**Average Composition**
Characterization					
Origin	Grünentsorgung	Rinde	Mutterboden	…………………	…………………
Type	Compost	Rindenkompost	Erdsubstrate	…………………	…………………
Amount per Year (in tons or m3)			…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	X	X	X	☐	☐
Size reduction	X	X	☐	☐	☐
Aerobic pre-treatment	X	X	☐	☐	☐
Hygienization	X	X	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	50 % od ……..…. g/l	35 % od ……..…. g/l	70 % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
VS-content	30 % od ……..…. g/l	80 % od ……..…. g/l	10 % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
COD	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
X Hygienization	X Sieving	☐ Biological treatment
X Other : Zerrkleinerung	☐ Other:………………	X Other: Composting
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	4'000 t or…….. ……..… m^3	1'500 t or ……..… m^3	2'500 t or ……..… m^3	……..… t or ……..… m^3
Is the amount estimated or measured?	Yes	No	No	No
Composition				
DM-content	35 % or…….. ……...… g/l	25-30 % or ……...… g/l	15 % or……...… g/l	……...… % or ……...… g/l
VS-content	70 % or ……...… g/l	% or ……...… g/l	% or ……...… g/l	……...… % or ……...… g/l
COD	……...… mg/l	……...… mg/l	……...… g/l	……...… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other: Composting	X Composting	X Composting	X Composting	☐ ……………..
Product Quality				
The product corresponds to a legal requirement	X	X	X	☐.....................
a label product	☐	☐	☐	☐.....................
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	Digester(s)
Dimensioning	
Number of digesters	1
Volume of each digester	.... / .... / 500 m^3
Input Material	
Consistency	[x] Solid (> 15% TS) [ ] Liquid (=< 15% TS)
Maximum diameter	30 mm
Type of digester	
Operation	**Batch**
Digestion temperature	55 °C
Make & Type of digester	Linde BRV
Provider	Linde BRV
Internal or external heat exchanger	Yes
Mixing	
Mixing with compressed biogas	X
Mechanical Stirrer	X
Hydraulic stirring	[ ]
Other	[ ]
None	[ ]

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	1		…………………
Volume of each digester	……/………/ 480 m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	30 mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**Batch**	or ……………t	**Batch** / **Continuous**
Digestion temperature	55 °C		………………… °C
Make/type of digester	BRV		……………..
Provider	BRV		…………………
External heat exchanger	**Yes**		**Yes/No**
Mixing			
Mixing with compressed biogas	X		☐
Mechanical stirrers	X		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 380'000 m3 | Nicht verwendete Biogasmenge (Fackel): 4'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a

falls ja::

CH_4 :	51-60	% vol
CO_2 :	30	% vol
H_2S :	100	**p**pm
Andere : ………..	………..	**p**pm

- Gibt es einen Gasspeicher ? : **Ja**

falls ja, Speichergrösse : 900 m3

Typ :
- X Foliengasspeicher
- ☐ Wassertassengasometer
- ☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	50-60	% vol
CO_2 :	20-30	% vol
H_2S :	20………..	**p**pm
Andere : ………..	………..	**p**pm

Art der Biogas-Aufbereitung :
- ☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
- X Aktivkohle
- ☐ Membran
- ☐ Andere:

Electricity Production **Yes/No**

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell

- Total installed power : 220 kWel.

- Number of generators : 1

- Gross electricity production : 640'000 kWh

- Utilization of produced electricity :

Sale to third party		kWh
Self-consumption	640'000	kWh

Heat Production **Yes/No**

- Type of heat production :
  - X Boiler: Steam
  - X Air heat exchanger
  - ☐ Heat from CHP
  - ☐ Other : ……………………

- Total installed power : von BHKW kWth.

- Gross heat production : 1'200'000 kWh

- Utilization of produced heat :

Sale to third party	………....	kWh
Self-consumption	100 %	kWh

Other Utilization of the Biogas **Yes**

- X Injection into the gas grid: 0 m3/a
- ☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (SFr.)	
Gross Investment Cost Fermentation + Composting	21,000,000	
thereof subsidies		none
thereof auto-construction (cost savings)		
Part of Plant		
Digester(s)	....	
Upgrading and utilization of biogas	....	
Other	………………..	

Income

	Amount (SFr.)
Electricity	640'000 / kWh
Heat	1'200'000./ kWh
Other utilization of biogas	none /kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount
Operation and maintenance; if possible: - labor cost	
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount
Per Ton	90/t

Success and failures

Bachenbülach

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address Name	Kompogas AG	Kompogas AG	Bühler AG + Kogas AG
Street	Rohrstrasse 36	Kasernenstr.	Sonnenhügelstrasse 3
Town	CH-8162 Glattbrugg	CH-8184 Bachenbülach	CH-9240 Uzwil
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 1 809 71 00	+41 1 862 11 70	+41 71 955 77 77
Fax :	+41 1 809 71 10	+41 1 862 11 70	+41 71 955 77 79
E-mail :	info@kompogas.ch		leisner@kogas.ch
Contact Person Name	Herr D. Kern	Herr K. Iten	Herr R. Leisner
Function	Technischer Leiter	Betriebsleiter	stv. Geschäftsführer
Status	☐ Public X Private ☐ Other : ………	☐ Public X Private ☐ Other : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

350 m2

Construction time

Start of construction: 1993

Start-up of plant: 1994

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Community	Grossverteiler	Gastgewerbe	…………………	…………………
Type	Bio waste	Marktabfälle	Speiseresten	…………………	…………………
Amount per Year (in tons or m3)	6'900 t	700 t	1'000 t	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	X	☐	☐
Aerobic pre-treatment	X	X	X	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	X	X	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	38 % od …….…. g/l	22 % od …….…. g/l	18 % od …….…. g/l	…….…. % od …….…. g/l	35.5 % od. …….…. g/l
VS-content	68 % od …….…. g/l	85 % od …….…. g/l	90 % od …….…. g/l	…….…. % od …….…. g/l	71 % od. …….…. g/l
COD	…….…. g/l	…….…. g/l	…….…. g/l	…….…. g/l	…….…. g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Es erfolgt keine kontinuierliche Analyse des Inputmaterials auf deren Zusammensetzung

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	X Sieving	☐ Biological treatment
☐ Other :…………………….	☐ Other:………………	☐ Other:………………
☐ None	☐ None	X None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or 7'500 m^3	……..… t or 2'500 m^3	……..… t or 3'800 m^3	200 t or ……..… m^3
Is the amount estimated or measured?	**No**	**Yes**	**Yes**	**Yes**
Composition				
DM-content	21.5 % or…….. ……..… g/l	40 % or ……..… g/l	15 % or……..… g/l	……..… % or ……..… g/l
VS-content	55 % or ……..… g/l	55 % or ……..… g/l	55 % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	X	X	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	X
Other:...............................	X n.A.	X gardening	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Fibl-Hilfsstoffliste	X Fibl-Hilfsstoffliste	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 260 / 260 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	Kompogas ZAF
Provider	Bühler AG + Kogas AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ ……………..........
None	☐

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 800'000 m3 Nicht verwendete Biogasmenge (Fackel): 10'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : Ja

falls ja::

CH_4 :	ca.. 60	% vol
CO_2 :	ca. 40	% vol
H_2S :	<450	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : **Ja / Nein**

falls ja, Speichergrösse : 50 m3

Typ :
- X Foliengasspeicher
- ☐ Wassertassengasometer
- ☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : Ja

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	>96	% vol
CO_2 :	< 4	% vol
H_2S :	< 5	ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :
- ☐ Nasswäscher: Wasser / **org.** Lösungsmittel
- X Aktivkohle
- ☐ Membran
- ☐ Andere

Electricity Production **Ja**

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell
- Total installed power : 170 kWel.
- Number of generators : 2
- **Gross electricity production :** 370'000 kWh
- Utilization of produced electricity :

Sale to third party	210'000 kWh
Self-consumption	460'000 kWh

Heat Production **Ja**

- Type of heat production :
  - ☐ Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - ☐ Heat from CHP
  - X Other : CHP
- Total installed power : 455 kWth.
- **Gross heat production :** 1'800'000 kWh
- Utilization of produced heat :

Sale to third party	0 kWh
Self-consumption	900'000 kWh

Other Utilization of the Biogas **Yes**

- X Injection into the gas grid: 440'000 m3/a
- ☐ Fuel : m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (Unit**)**
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Braunschweig

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name		Braunschweiger Kompost GmbH	Bühler AG
Street		Celler Heerstrasse 337	
Town		D-38112 Braunschweig	CH-9240 Uzwil
Country		Germany	Switzerland
Telefone		+49 530 337 49	+41 71 955 11 11
Fax :		+49 530 337 40	
E-mail :		kompost-bs@t-online.de	
Contact Person Name		H. Kokott / H. Bode	
Function			
Status	☐ Public ☐ Private ☐ Other : ……	☐ Public ☐ Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
X	Reduction of Waste Volume or Weight
X	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
……	Rentability as compared to other Processes
……	Other

Surface required for treatment

.... m2

Construction time

Start of construction:

Start-up of plant: 1997

Remarks

Description of the Main Substrates

SUBSTRAT	**Substrate n°1**	**Substrate n°2**	**Substrate n°3**	**Substrate n°4**	**Average Composition**
Characterization					
Origin	Braunschweig	…………………	…………………	…………………	…………………
Type	Biowaste	…………………	…………………	…………………	…………………
Amount per Year (in tons or m3)	ca. 16'000	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	X	☐	☐	☐	☐
Size reduction	X	☐	☐	☐	☐
Aerobic pre-treatment	X	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	39 % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
VS-content	50 - 70 % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
COD	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	X Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	X Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	ca. 16'000 t or…….. ……..… m^3	……..… t or ……..… m^3	……..… t or ……..… m^3	……..… t or ……..… m^3
Is the amount estimated or measured?	Yes/No	Yes/No	Yes/No	Yes/No
Composition				
DM-content	20 - 30 % or…….. ……...… g/l	……...… % or ……...… g/l	ca. 5 % or……...… g/l	……...… % or ……...… g/l
VS-content	50 - 70 % or ……...… g/l	……...… % or ……...… g/l	……...… % or ……...… g/l	……...… % or ……...… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……...… g/l
Utilization of digestate				
Agricultural Application	☐	X	☐	☐
Waste water treatment plant	☐	☐	X	☐
Landfill	☐	☐	☐	X
Incineration	☐	☐	☐	☐
Other:...............................	X Composting	☐ ……………..	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	X	X	X	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	Digester(s)
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 840 / 840 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	20 - 30 mm
Type of digester	
Operation	Batch / **Continuous**
Digestion temperature	ca. 57 °C
Make & Type of digester	……………..
Provider	Bühler AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ …………….........
None	☐

Remarks

Double Stage Digestion

Digestion	First Stage Type of Digester 1	Intermediate Treatment (Please describe)	Second Stage Type of Digester 2
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	Batch /Continuous	or ……………t	Batch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ …………..........		☐ …………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 1'698'246 m3 Nicht verwendete Biogasmenge (Fackel): 7'835 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a / **N**ein

falls ja::

CH4 : 59.3 % vol

CO2 : ……….. % vol

H2S : ……….. **p**pm

Andere : ……….. ……….. **p**pm

- Gibt es einen Gasspeicher ? : **Ja**

falls ja, Speichergrösse : 100 m3

Typ : X Foliengasspeicher

☐ Wassertassengasometer

☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **N**ein

falls ja: Gaszusammensetzung nach Reinigung

CH4 : ……….. % vol

CO2 : ……….. % vol

H2S : ………... **p**pm

Andere : ……….. ……….. **p**pm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel

☐ Aktivkohle

☐ Membran

☐ Andere

Electricity Production **Yes/No**

- Type of electricity production :

☐ CHP

☐ Gas turbine

☐ Steam turbine

☐ Fuel Cell

- Total installed power : .... kWel.

- Number of generators : ....

- Gross electricity production : …………….. kWh

- Utilization of produced electricity :

Sale to third party …………….. kWh

Self-consumption …………….. kWh

Heat Production **Yes/No**

- Type of heat production :

☐ Boiler: Steam/Heat

☐ Air heat exchanger

☐ Heat from CHP

☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : …………….. kWh

- Utilization of produced heat :

Sale to third party …………….. kWh

Self-consumption …………….. kWh

Other Utilization of the Biogas **Yes/No**

☐ N Injection into the gas grid

☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (DM)
Gross Investment Cost	19,743,060
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	oben enthalten
Upgrading and utilization of biogas	oben enthalten
Other	………………..

Income

	Amount (DM)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	0.20/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 : Biowaste till 06/01	135.--/t or /m3
Substrate 1: Biowaste from 07/01	183.--/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (DM)
Operation and maintenance; if possible: - labor cost	
maintenance cost	3,572,200
Capital cost	5,076,729
Other	5,076,000

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Etat Genève

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Etat de Genève		Valorga Steinmüller
Street			
Town	CH-1205 Genève		
Country	Switzerland		
Telefone	+41 22 727 05 20		
Fax :	+41 22 727 05 25		
E-mail :	claude.calame@etat-ge.ch		
Contact Person			
Name	Claude Calame		
Function	Director		
Status	X Public ☐ Private ☐ Other : ……	☒ Public ☐ Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
……	Rentability as compared to other Processes
……	Other

Surface required for treatment

2'000 m2

Construction time

Start of construction: February 1999

Start-up of plant: November 2000

Remarks

Description of the Main Substrates

SUBSTRAT	**Substrate n°1**	**Substrate n°2**	**Substrate n°3**	**Substrate n°4**	**Average Composition**
Characterization					
Origin	Biowaste	Agricultural waste	…………………	…………………	…………………
Type	Yard waste/kitchen waste	Yard & field waste	…………………	…………………	…………………
Amount per Year (in tons or m3)	4000	500	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☒	☒	☐	☐	☐
Size reduction	☒	☒	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	30 to 35% od ……..… g/l	40% od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
VS-content	50 to 80 % od ……..… g/l	60 to 70% od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
Yes Press	Drying	Yes Flocculation
Sedimentation Tank	Yes Composting	Centrifugation
Centrifugation	Size reduction	Yes Filtration
Hygienization	Yes Sieving	Biological treatment
Other :…………………….	Other:………………	Other:………………
None	None	None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or…….. ……..… m^3	……600 t or ……..… m^3	……..… t or …18'000 m^3	……450 t or ……..… m^3
Is the amount estimated or measured?	**Yes/No**	**Measured**	**Measured**	**Measured**
Composition				
DM-content	……..… % or…….. ……..… g/l	……37 % or ……..… g/l	……..… % or……..… g/l	……..… % or ……..… g/l
VS-content	……..… % or ……..… g/l	…50 to 70 % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	Yes		
Waste water treatment plant	☐	No	Yes	
Landfill	☐	No		
Incineration	☐	No		Yes
Other:................................	☐ ……………..	☐ ……………..	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	☐Yes	☐...No..................	☐.....................
a label product	☐.....................	☐No	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	1
Volume of each digester	1000 m3
Input Material	
Consistency	☒ Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	50 to 55°C
Make & Type of digester	Valorga Steel Cylinder
Provider	Valorga Steinmüller
Internal or external heat exchanger	external addition of steam
Mixing	
Mixing with compressed biogas	Yes
Mechanical Stirrer	
Hydraulic stirring	Yes
Other	……………..........
None	

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Annual Energy balance

Gross Biogas-Production:…………286'000.m3 Not utilized gas (flare):.....37'500................ m3

Raw Biogas

- Is the gas produced analyzed?: Ja / Nein

if yes:

CH_4 :	……53 % vol
CO_2 :	……….. % vol
H_2S :	……….. ppm
Other	……….. ppm

- Is there a gas storage? : **Yes**

if yes, what size? 500m3

Typ : ☒ Rubber balloon
☐ Water bell
☐ Other

Biogas upgrading

- Is the Biogas upgraded? : **No**

if yes: gas quality after treatment

CH_4 :	……….. % vol
CO_2 :	……….. % vol
H_2S :	……….. ppm
Other : ………..	……….. ppm

Type of biogas upgrading

☐ Washer
☐ Activated carbone
☐ Membranes
☐ Other

Electricity Production **Yes**

- Type of electricity production :

☒ CHP
☐ Gas turbine
☐ Steam turbine
☐ Fuel Cell

- Total installed power : ....400 kWel.
- Number of generators : ....2.

- Gross electricity production : ………435'000 kWh

- Utilization of produced electricity :

Sale to third party	………160'000 kWh
Self-consumption	……160'000 kWh

Heat Production **Yes/No**

- Type of heat production :

☐ Boiler: Steam/Heat
☐ Air heat exchanger
☒ Heat from CHP
☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : …………….. kWh

- Utilization of produced heat :

Sale to third party	…………….. kWh
Self-consumption	…………….. kWh

Other Utilization of the Biogas **No**

☐ N Injection into the gas grid
☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

ISKA

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	ISKA GmbH	T-Plus	ISKA GmbH
Street	Am Erlengraben 3	Göthestrasse 15a	Am Erlengraben 3
Town	76275 Ettlingen	76275 Ettlingern	76275 Ettlingen
Country	Germany	Germany	Germany
Telefone		+49-5057 890	
Fax :		+49-5057 899	
E-mail :	info@iska-gmbh.de	info@t-plus.de	info@iska-gmbh.de
Contact Person			
Name	Thomas Engelhard		Thomas Engelhard
Function	Director		Director
Status	☐ Public X Private ☐ Other : ……	☐ Public X Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

	Energy Production
……	Production of Compost
X	Reduction of Waste Volume or Weight
X	Reduction of the Organic Fraction
……	Marketing/PR
	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

……………m2

Construction time

Start of construction:..................

Start-up of plant:.......................

Remarks

The technology has been built in 30'000 TPY demonstration unit. The operational data are based on this unit.
The financial data are based on a project which will be constructed in Croatia during 2003.

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Household	…………………	…………………	…………………	…………………
Type	Waste	…………………	…………………	…………………	…………………
Amount per Year (in tons or m3)	…………………	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	☐	☐	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	X Percolation	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	60 % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od. …….…. g/l
VS-content	…….…. % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od …….…. g/l	…….…. % od. …….…. g/l
COD	…….…. g/l	…….…. g/l	…….…. g/l	…….…. g/l	…….…. g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading SNAP	**Upgrading Solid Phase**	**Upgrading Liquid Phase**
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	X Biological treatment
☐ Other :……………………	☐ Other:………………	X Other: Digestion
☐ None	☐ None	☐ None

	Digestate	**Solid Phase**	**Liquid Phase**	**Remaining Fraction**
Quantity				
Quantity per year	140'000 t or…….. ……..… m^3	39'000 t or ……..… m^3	10'000 t or ……..… m^3	……..… t or ……..… m^3
Is the amount estimated ?	**Yes/No**	**Yes**	**Yes**	**Yes/No**
Composition				
DM-content	……..… % or…….. ……..… g/l	54 % or ……..… g/l	< 2 % or……..… g/l	……..… % or ……..… g/l
VS-content	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:................................	☐ ……………..	☐……………..	X Recycled	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.................	X	X	☐.....................
a label product	☐.................	☐................	☐	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

The solid phase is aerobically upgraded, the liquid phase is digested, denitrified, cleaned by nanofiltration and recycled

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	1
Volume of each digester	……/………/ 4'000 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	35 °C
Make & Type of digester	Hybrid Filter
Provider	ISKA
Internal or external heat exchanger	no
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	☐
Hydraulic stirring	☐
Other	☐ ……………….........
None	X

Remarks

A hybrid filter is not stirred

There is compressed gas to clean the filter bodies

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ …………..........		☐ …………..........
None	☐		☐

Remarks

Biogas Utilization

Yearly Energy Balance

Gros Biogas-Production: 3'500'000 m3 Excess Biogas (Flare):..................... m3

Raw Biogas
- Is the gas composition analyzed: Yes / No
  if yes::

CH_4 :	70 % vol
CO_2 :	30 % vol
H_2S :	5-10'000 ppm
Other : ………..	……….. ppm

- Is there a gas container? : **Yes / No**
  if yes, give size : 10'000 m3
  Type : ☐ Gas balloon
  ☐ Steel bell
  ☐ Other : ………..

Biogas Upgrading
- Is the biogas upgraded? : **Yes / No**
  if yes: Gas composition after treatment

CH_4 :	70 % vol
CO_2 :	30 % vol
H_2S :	< 500 ppm
Other : ………..	……….. ppm

Type of gas upgrading :
X Washer:
☐ Activated carbon
☐ Membrane
☐ Other

Electricity Production ***Yes***

- Type of electricity production :
  X CHP
  ☐ Gas turbine
  ☐ Steam turbine
  ☐ Fuel Cell

- Total installed power : 1'2 MWel.
- Number of generators : 3

- Gross electricity production : 7.6 GWh
- Utilization of produced electricity :

Sale to third party 1.3 GWh
Self-consumption …………….. kWh

Heat Production **Yes/No**

- Type of heat production :
  ☐ Boiler: Steam/Heat
  ☐ Air heat exchanger
  X Heat from CHP
  ☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : …………….. kWh
- Utilization of produced heat :

Sale to third party …………….. kWh
Self-consumption …………….. kWh

Other Utilization of the Biogas **Yes/No**

☐ N Injection into the gas grid
☐ Fuel :………………………..m3/a

Remarks

500'000 m^3 is used for regenerative thermal oxidation (incineration of polluted air)

Economy

Investment Cost

	Amount (Euro)
Gross Investment Cost	18.3 Mio.
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Euro)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 : No fixed price (pu to 100 Euro/t)	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (Euro)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Euro)
Per Ton	20.5 Euro/t

Success and failures

No major problems

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Landkreis München	Ganser Entsorgungsbetriebe	MAT
Street	Maria-Hilf-Platz 17	Taufkirchner Strasse 1	Gotthartstr. 42
Town	D-81541 München	D-85649 Kirchstockach	D-80686 München
Country	Germany	Germany	Germany
Telefone	+49 89 622 125 27	+49 81 028 51 70	+49 89 589 390 100
Fax :	+49 89 622 122 78	+49 81 028 51 72	+49 89 589 390 110
E-mail :			
Contact Person			
Name	Herr Moser	Ulrich Niefnecker	Harry Wiljan
Function	Department head	Engineer	Manager
Status	X Public ☐ Private ☐ Other : ……	☐ Public X Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
……	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
……	Rentability as compared to other Processes
X	Other: keine Handsortierung

Surface required for treatment

10'000 m2

Construction time

Start of construction: 1996

Start-up of plant: 1997

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Landkreis u. Stadt München	…………………	…………………	…………………	…………………
Type	Biowaste	…………………	…………………	…………………	…………………
Amount per Year (in tons or m3)	25,000	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	☐	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	X: BTA-Pulver	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	32 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
VS-content	69 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
X Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	X Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	50'000 t or…….. ……..… m^3	8'500 t or ……..… m^3	41'500 t or ……..… m^3	……..… t or ……..… m^3
Is the amount estimated or measured?	Yes/No	Yes/No	Yes/No	Yes/No
Composition				
DM-content	8 % or…….. ……..… g/l	34 % or ……..… g/l	……..… % or 3 g/l *	……..… % or ……..… g/l
VS-content	6 % or ……..… g/l	24 % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:...............................	☐ ……………..	X Composting	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Bioabfall VO	☐.....................	☐.....................
a label product	☐.....................	X Gütegemeinsch. bayrisch. Komposthersteller	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

* gemessen als abfiltrierbare Stoffe

Single Stage Digestion

<u>Digestion</u>	**Digester(s)**
<u>Dimensioning</u>	
Number of digesters	…………………
Volume of each digester	……/………/…… m^3
<u>Input Material</u>	
Consistency	☐ Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
<u>Type of digester</u>	
Operation	<u>B</u>atch / **<u>Continuous</u>**
Digestion temperature	………………… °C
Make & Type of digester	……………..
Provider	…………………
Internal or external heat exchanger	yes/no
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	☐
Hydraulic stirring	☐
Other	☐ …………….........
None	☐

<u>Remarks</u>

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	2		1
Volume of each digester	……/ 550 / 550 m^3		……/………/ 1'280 m^3
Input Material			
Consistency	Solid (> 15% TS) X Liquid (=< 15% TS)		Solid (> 15% TS) X Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	Continuous	or ……………t	Continuous
Digestion temperature	37 °C		37 °C
Make/type of digester	voll durchmischt; Hydrolyse		Festbettreaktor
Provider	MAT		MAT, Ph. Müller
External heat exchanger	**Yes**		**Yes**
Mixing			
Mixing with compressed biogas	X		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		X
Other	☐ …………….........		☐ …………….........
None	☐		☐

Remarks

Biogas Utilization

Järliche Energiebilanz

Brutto Biogas-Produktion: 1'500 m3 Nicht verwendete Biogasmenge (Fackel): 200'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a / **N**ein

falls ja::

CH_4 :	62	% vol
CO_2 :	………..	% vol
H_2S :	………..	**p**pm
Andere : ………..	………..	**p**pm

- Gibt es einen Gasspeicher ? : **Nein**

falls ja, Speichergrösse :……………….m3

Typ :
- ☐ Foliengasspeicher
- ☐ Wassertassengasometer
- ☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **N**ein

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	………..	% vol
CO_2 :	………..	% vol
H_2S :	………...	**p**pm
Andere : ………..	………..	**p**pm

Art der Biogas-Aufbereitung :
- ☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
- ☐ Aktivkohle
- ☐ Membran
- ☐ Andere

Electricity Production **Yes**

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell

- Total installed power : 520 kWel.

- Number of generators : 2

- Gross electricity production : 3'000'000 kWh

- Utilization of produced electricity :

Sale to third party	900'000 kWh
Self-consumption	2'100'000 kWh

Heat Production **Yes/No**

- Type of heat production :
  - ☐ Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - X Heat from CHP
  - ☐ Other : ……………………

- Total installed power : 820 kWth.

- Gross heat production : …………….. kWh

- Utilization of produced heat :

Sale to third party	…………….. kWh
Self-consumption	…………….. kWh

Other Utilization of the Biogas **Yes/No**

- ☐ N Injection into the gas grid
- ☐ Fuel :……………………….m3/a

Remarks

Biogasproduktion gering, da hoher Anteil von Gartenabfällen im Bioabfall (51%). Stadt München schl....
in Sammelkiste allse Gekochte aus

Economy

Investment Cost

	Amount (€)
Gross Investment Cost	9.0 Mio
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (€)
Electricity	0.1022/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :Rechengut	50/t or /m3
Substrate 2 : Schwergut	50/t or /m3
Substrate 3 : Sand	15/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (€)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	1,375,000.00
Other	1,375,000.00

Total treatment cost

	Amount (€)
Per Ton	55.--

Success and failures

Niederuzwil

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			Bühler AG +
Name	Bioverwertungs AG	Bioverwertungs AG	Kogas AG
Street	Grueben	Grueben	Sonnenhügelstrasse 3
Town	CH-9244 Niederuzwil	CH-9244 Niederuzwil	CH-9240 Uzwil
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 71 952 61 61	+41 71 952 61 61	+41 71 955 77 77
Fax :	+41 71 952 61 62	+41 71 952 61 62	+41 71 955 77 79
E-mail :			leisner@kogas.ch
Contact Person Name	Herr T. Huwiler	Herr M. Egg	Herr R. Leisner
Function	Geschäftsführer	Betriebsleiter	stv. Geschäftsführer
Status	☐ Public X Private ☐ Other : ………	☐ Public X Private ☐ Other : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

450 m2

Construction time

Start of construction: 1997

Start-up of plant: 1998

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Community	Grossverteiler	Gardening	…………………	…………………
Type	Bio waste	Marktabfälle	Grüngut	…………………	…………………
Amount per Year (in tons or m3)	8'000 t	1'500 t	500 t	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	X	☐	☐
Aerobic pre-treatment	X	X	X	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	X	X	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	40 % od ………... g/l	22 % od ………... g/l	40 % od ………... g/l	………... % od ………... g/l	37 % od ………... g/l
VS-content	65 % od ………... g/l	85 % od ………... g/l	60 % od ………... g/l	………... % od ………... g/l	67 % od. ………... g/l
COD	………... g/l	………... g/l	………... g/l	………... g/l	………... g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Es erfolgt keine kontinuierliche Analyse des Inputmaterials auf deren Zusammensetzung

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	X Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	X None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	…….…. t or 8'800 m^3	…….…. t or 3'400 m^3	…….…. t or 3'900 m^3	160 t or …….…. m^3
Is the amount estimated or measured?	No	Yes	Yes	Yes
Composition				
DM-content	21.5 % or…….. …….…. g/l	45 % or …….…. g/l	15 % or…….…. g/l	…….…. % or …….…. g/l
VS-content	55 % or …….…. g/l	55 % or …….…. g/l	55 % or …….…. g/l	…….…. % or …….…. g/l
COD	…….…. mg/l	…….…. mg/l	…….…. g/l	…….…. g/l
Utilization of digestate				
Agricultural Application	☐	X	X	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	X
Other:...............................	X n.A.	X gardening	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Fibl-Hilfsstoffliste	X Fibl-Hilfsstoffliste	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 605 / 295 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	55 mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	Kompogas ZAG/ZAR
Provider	Bühler AG + Kogas AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ ……………….........
None	☐

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ …………….........		☐ …………….........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 870'000 m3 Nicht verwendete Biogasmenge (Fackel): 50'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **Ja**

falls ja::

CH4 :	ca.. 60	% vol
CO2 :	ca. 40	% vol
H2S :	<450	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : **Ja / Nein**

falls ja, Speichergrösse : 70 m3

Typ : X Foliengasspeicher
☐ Wassertassengasometer
☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **N**ein

falls ja: Gaszusammensetzung nach Reinigung

CH4 :		% vol
CO2 :		% vol
H2S :		ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
☐ Aktivkohle
☐ Membran
☐ Andere

Electricity Production **Ja**

- Type of electricity production :

X CHP
☐ Gas turbine
☐ Steam turbine
☐ Fuel Cell

- Total installed power : 170 kWel.

- Number of generators : 2

- Gross electricity production : 1'420'000 kWh

- Utilization of produced electricity :

Sale to third party	930'000 kWh
Self-consumption	490'000 kWh

Heat Production **Ja**

- Type of heat production :

☐ Boiler: Steam/Heat
☐ Air heat exchanger
☐ Heat from CHP
X Other : CHP

- Total installed power : 455 kWth.

- Gross heat production : 3'800'000 kWh

- Utilization of produced heat :

Sale to third party	0 kWh
Self-consumption	1'050'000 kWh

Other Utilization of the Biogas **Yes**

☐ Injection into the gas grid: m3/a

☐ Fuel :...........m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Otelfingen

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Kompogas AG	Kompogas AG	Bühler AG + Kogas AG
Street	Libernstrasse 16	Libernstrasse 16	Sonnenhügelstrasse 3
Town	CH-8112 Otelfingen	CH-8112 Otelfingen	CH-9240 Uzwil
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 1 844 08 00	+41 1 844 08 00	+41 71 955 77 77
Fax :	+41 1 844 08 02	+41 1 844 08 02	+41 71 955 77 79
E-mail :			leisner@kogas.ch
Contact Person Name	Herr D. Kern	Herr E. Hartmann	Herr R. Leisner
Function	Technischer Leiter	Betriebsleiter	stv. Geschäftsführer
Status	☐ Public X Private ☐ Other : ………	☐ Public X Private ☐ Other : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

750 m2

Construction time

Start of construction: 1995

Start-up of plant: 1996

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Community	Grossverteiler	Gastgewerbe	…………………	…………………
Type	Bio waste	Marktabfälle	Speiseresten	…………………	…………………
Amount per Year (in tons or m3)	10'500 t	1'500 t	500 t	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	X	☐	☐
Aerobic pre-treatment	X	X	X	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	X	X	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	38 % od ……..…. g/l	22 % od ……..…. g/l	18 % od ……..…. g/l	……..…. % od ……..…. g/l	35 % od ……..…. g/l
VS-content	68 % od ……..…. g/l	85 % od ……..…. g/l	90 % od ……..…. g/l	……..…. % od ……..…. g/l	67 % od. ……..…. g/l
COD	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Es erfolgt keine kontinuierliche Analyse des Inputmaterials auf deren Zusammensetzung

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	X Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	X None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or 11'000 m^3	……..… t or 3'900 m^3	……..… t or 5'200 m^3	200 t or ……..… m^3
Is the amount estimated or measured?	No	Yes	Yes	Yes
Composition				
DM-content	22 % or…….. ……..… g/l	40 % or ……..… g/l	15 % or……..… g/l	……..… % or ……..… g/l
VS-content	55 % or ……..… g/l	55 % or ……..… g/l	55 % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	X	X	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	X
Other:...............................	X n.A.	X gardening	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Fibl-Hilfsstoffliste	X Fibl-Hilfsstoffliste	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	1
Volume of each digester	……/...... / 840 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	55 mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	Kompogas ZAH
Provider	Bühler AG + Kogas AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ ……………..........
None	☐

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 820'000 m3 Nicht verwendete Biogasmenge (Fackel): 15'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a

falls ja::

CH_4 :	ca.. 60	% vol
CO_2 :	ca. 40	% vol
H_2S :	<450	**p**pm
Andere : ………..	………..	**p**pm

- Gibt es einen Gasspeicher ? : **Ja / Nein**

falls ja, Speichergrösse : 70 m3

Typ : X Foliengasspeicher
☐ Wassertassengasometer
☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	>96	% vol
CO_2 :	< 4	% vol
H_2S :	< 5	**p**pm
Andere : ………..	………..	**p**pm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
X Aktivkohle
☐ Membran
☐ Andere

Electricity Production **Ja**

- Type of electricity production :
X CHP
☐ Gas turbine
☐ Steam turbine
☐ Fuel Cell

- Total installed power : 265 kWel.

- Number of generators : 2

- Gross electricity production : 1'695'000 kWh

- Utilization of produced electricity :

Sale to third party	1'060'000 kWh
Self-consumption	635'000 kWh

Heat Production **Ja**

- Type of heat production :
☐ Boiler: Steam/Heat
☐ Air heat exchanger
☐ Heat from CHP
X Other : CHP

- Total installed power : 710 kWth.

- Gross heat production : 4'565'000 kWh

- Utilization of produced heat :

Sale to third party	0 kWh
Self-consumption	1'260'000 kWh

Other Utilization of the Biogas **Yes**

☐ Injection into the gas grid: m3/a

X Fuel :60'000 .m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Rümlang

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Kompogas AG	Kompogas AG	W. Schmid AG + Kogas AG
Street	Rohrstrasse 36	Wibachstrasse	Rohrstrasse 36
Town	CH-8162 Glattbrugg	CH-8153 Rümlang	CH-8162 Glattbrugg
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 1 809 71 00	+41 1 817 10 56	+41 71 955 77 77
Fax :	+41 1 809 71 10	+41 1 817 10 56	+41 71 955 77 79
E-mail :	info@kompogas.ch		leisner@kogas.ch
Contact Person Name	Herr D. Kern	Herr E. Barmettler	Herr R. Leisner
Function	Technischer Leiter	Betriebsleiter	stv. Geschäftsführer
Status	☐ Public X Private ☐ Other : ………	☐ Public X Private ☐ Other : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

450 m2

Construction time

Start of construction: 1991

Start-up of plant: 1992

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Community	Community	Gastgewerbe	…………………	…………………
Type	Grüngut	Marktabfälle	Speiseresten	…………………	…………………
Amount per Year (in tons or m3)	6'000 t	500 t	500 t	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	X	☐	☐
Aerobic pre-treatment	X	X	X	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	X	X	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	38 % od ……..… g/l	22 % od ……..… g/l	18 % od ……..… g/l	……..… % od ……..… g/l	35.5 % od. ……..… g/l
VS-content	68 % od ……..… g/l	85 % od ……..… g/l	90 % od ……..… g/l	……..… % od ……..… g/l	71 % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Es erfolgt keine kontinuierliche Analyse des Inputmaterials auf deren Zusammensetzung

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
X Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	X Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	X None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or…….. 6'000 m^3	……..… t or 2'000 m^3	……..… t or 3'300 m^3	100 t or ……..… m^3
Is the amount estimated or measured?	**No**	**Yes**	**Yes**	**Yes**
Composition				
DM-content	20.5 % or…….. ……..… g/l	40 % or ……..… g/l	15 % or……..… g/l	……..… % or ……..… g/l
VS-content	55 % or ……..… g/l	55 % or ……..… g/l	55 % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	X	X	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	X
Other:...............................	X n.A.	X gardening	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Fibl-Hilfsstoffliste	X Fibl-Hilfsstoffliste	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 165 / 295 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	Kompogas ZAR
Provider	Kogas AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ ……………..........
None	☐

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 800'000 m3 Nicht verwendete Biogasmenge (Fackel): 10'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a

falls ja::

CH_4 :	ca.. 60	% vol
CO_2 :	ca. 40	% vol
H_2S :	<450	**p**pm
Andere : ………..	………..	**p**pm

- Gibt es einen Gasspeicher ? : **Ja / Nein**

falls ja, Speichergrösse : 50 m3

Typ :
X Foliengasspeicher
☐ Wassertassengasometer
☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	>96	% vol
CO_2 :	< 4	% vol
H_2S :	< 5	**p**pm
Andere : ………..	………..	**p**pm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
X Aktivkohle
☐ Membran
☐ Andere

Electricity Production **Ja**

- Type of electricity production :
X CHP
☐ Gas turbine
☐ Steam turbine
☐ Fuel Cell

- Total installed power : 170 kWel.
- Number of generators : 2

- Gross electricity production : 1'300'000 kWh

- Utilization of produced electricity :

Sale to third party	930'000 kWh
Self-consumption	370'000 kWh

Heat Production **Ja**

- Type of heat production :
☐ Boiler: Steam/Heat
☐ Air heat exchanger
☐ Heat from CHP
X Other : CHP

- Total installed power : 455 kWth.

- Gross heat production : 3'50'000 kWh

- Utilization of produced heat :

Sale to third party	1'200'000 kWh
Self-consumption	740'000 kWh

Other Utilization of the Biogas **Yes**

☐ N Injection into the gas grid

X Fuel : 50'000 .m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Samstagern

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address Name	Kompogas AG	Kompogas AG	Bühler AG + Kogas AG
Street	Bruggetenstr. 3	Bruggetenstr. 3	Sonnenhügelstrasse 3
Town	CH-8833 Samstagern	CH-8833 Samstagern	CH-9240 Uzwil
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 1 785 09 53	+41 1 785 09 53	+41 71 955 77 77
Fax :	+41 1 785 09 77	+41 1 785 09 77	+41 71 955 77 79
E-mail :			leisner@kogas.ch
Contact Person Name	Herr D. Kern	Herr B. Trütsch	Herr R. Leisner
Function	Technischer Leiter	Betriebsleiter	stv. Geschäftsführer
Status	☐ Public X Private ☐ Other : ………	☐ Public X Private ☐ Other : ………	

Various Information

Reasons for the Choice of the System

X	Energy Production
X	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
X	Rentability as compared to other Processes
……	Other

Surface required for treatment

350 m2

Construction time

Start of construction: 1994

Start-up of plant: 1995

Remarks

Description of the Main Substrates

SUBSTRAT	**Substrate n°1**	**Substrate n°2**	**Substrate n°3**	**Substrate n°4**	**Average Composition**
Characterization					
Origin	Community	Grossverteiler		…………………	…………………
Type	Bio waste	Marktabfälle		…………………	…………………
Amount per Year (in tons or m3)	6'700 t	1'000 t		…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	X	☐	☐	☐
Aerobic pre-treatment	X	X	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	X	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ ………	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	38 % od ……..… g/l	22 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	36 % od ……..… g/l
VS-content	70 % od ……..… g/l	85 % od ……..… g/l	……..… % od ……..… g/l	……..… % od ……..… g/l	71 % od. ……..… g/l
COD	……..… g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes**				

Remarks

Es erfolgt keine kontinuierliche Analyse des Inputmaterials auf deren Zusammensetzung

Upgrading and Utilization of the Digestate

Upgrading Digestate		Upgrading Solid Phase		Upgrading Liquid Phase	
X	Press	☐	Drying	☐	Flocculation
☐	Sedimentation Tank	X	Composting	☐	Centrifugation
☐	Centrifugation	☐	Size reduction	☐	Filtration
☐	Hygienization	X	Sieving	☐	Biological treatment
☐	Other :……………………	☐	Other:………………	☐	Other:………………
☐	None	☐	None	X	None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or 6'500 m^3	……..… t or 2'200 m^3	……..… t or 3'300 m^3	150 t or ……..… m^3
Is the amount estimated or measured?	**No**	**Yes**	**Yes**	**Yes**
Composition				
DM-content	21 % or…….. ……..… g/l	40 % or ……..… g/l	15 % or……..… g/l	……..… % or ……..… g/l
VS-content	55 % or ……..… g/l	55 % or ……..… g/l	55 % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	X	X	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	X
Other:...............................	X n.A.	X gardening	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐.....................	X Fibl-Hilfsstoffliste	X Fibl-Hilfsstoffliste	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 260 / 260 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	…………….. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	Kompogas ZAF
Provider	Bühler AG + Kogas AG
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	X
Hydraulic stirring	☐
Other	☐ …………….........
None	☐

Remarks

Double Stage Digestion

Digestion	First Stage Type of Digester 1	Intermediate Treatment (Please describe)	Second Stage Type of Digester 2
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Jährliche Energiebilanz

Brutto Biogas-Produktion: 820'000 m3 Nicht verwendete Biogasmenge (Fackel): 15'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : Ja

falls ja::

CH_4 :	ca.. 60	% vol
CO_2 :	ca. 40	% vol
H_2S :	<450	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : Ja / **Nein**

falls ja, Speichergrösse : 60 m3

Typ :
- X Foliengasspeicher
- ☐ Wassertassengasometer
- ☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : Ja

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	>96	% vol
CO_2 :	< 4	% vol
H_2S :	< 5	ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :
- ☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
- X Aktivkohle
- ☐ Membran
- ☐ Andere

Electricity Production **Ja**

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell

- Total installed power : 170 kWel.

- Number of generators : 2

- Gross electricity production : 715'000 kWh

- Utilization of produced electricity :

Sale to third party	315'000 kWh
Self-consumption	400'000 kWh

Heat Production **Ja**

- Type of heat production :
  - ☐ Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - ☐ Heat from CHP
  - X Other : CHP

- Total installed power : 455 kWth.

- Gross heat production : 1'920'000 kWh

- Utilization of produced heat :

Sale to third party	0 kWh
Self-consumption	800'000 kWh

Other Utilization of the Biogas **Yes**

- X Injection into the gas grid: 440'000 m3/a
- ☐ Fuel : m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	....
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	…..……………/ kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	Stadt Baden-Baden	Owner	BTA
Street	Brieglackerstr. 8		Rottmannstr. 18
Town	D-76532 Baden-Baden		D-80333 München
Country	Germany		Germany
Telefone	0049 722 193 15 10		+49 89 520 460-6
Fax :	0049 722 193 15 15		+49 89 523 2329
E-mail :	umweltamt@baden-baden.de		post@bta-technologie.de
Contact Person			
Name	Herr Schäfer		
Function			
Status	X Public ☐ Private ☐ Other : ……	X Public ☐ Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

x	Energy Production
x	Production of Compost
……	Reduction of Waste Volume or Weight
……	Reduction of the Organic Fraction
……	Marketing/PR
……	Subsidies as a Driver
x	Rentability as compared to other Processes
x	Other: Störstoff...., Homogenisierung

Surface required for treatment

ca. 200 m2

Construction time

Start of construction: 1992

Start-up of plant: 1.4.1993

Remarks

Der Bioabfall wird in Wasser aufgelöst und danach entwässert. Die Feststoffe gehen in die Kompostierung; das Zentrat in die Faultürme der Kläranlage

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Household and industrial waste	…………………	…………………	…………………	…………………
Type	Biowaste	…………………	…………………	…………………	…………………
Amount per Year (in tons or m3)	6'500 t/y	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	☐	☐	☐	☐	☐
Size reduction	X	☐	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	X	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	X ..... in Wasser	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	20 - 30 % od ………... g/l	………... % od ………... g/l	………... % od ………... g/l	………... % od ………... g/l	………... % od. ………... g/l
VS-content	………... % od ………... g/l	………... % od ………... g/l	………... % od ………... g/l	………... % od ………... g/l	………... % od. ………... g/l
COD	………... g/l	………... g/l	………... g/l	………... g/l	………... g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
X Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	X Biological treatment (Faulung)
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	6'500 t or…….... ……..… m^3	3'500 t or ……..… m^3	3'000 t or ……..… m^3	ca. 8% Input or ……..… m^3
Is the amount estimated or measured?	Yes	Yes	Yes	Yes/No
Composition				
DM-content	20-30 % or…….. ……..… g/l	30 % or ……..… g/l	1-2 % or……..… g/l	40 % or ……..… g/l
VS-content	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:................................	☐ ……………..	☐ ……………..	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to		X Bioabfall VO		
a legal requirement	☐.....................	Komposterlass	☐.....................	☐.....................
a label product	☐.....................	☐.....................	☐.....................	☐.....................
Other	…………………	…………………	…………………	…………………

Remarks

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	2
Volume of each digester	……/ 3'000 / 3'000 m^3
Input Material	
Consistency	☐ Solid (> 15% TS) X Liquid (=< 15% TS)
Maximum diameter	8 mm
Type of digester	
Operation	**B**atch
Digestion temperature	32 - 35 °C
Make & Type of digester	Beton
Provider	…………………
Internal or external heat exchanger	yes
Mixing	
Mixing with compressed biogas	X
Mechanical Stirrer	☐
Hydraulic stirring	X
Other	☐ ……………….........
None	☐

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ …………….........		☐ …………….........
None	☐		☐

Remarks

Järliche Energiebilanz

Brutto Biogas-Produktion: 4'000 m3 — Nicht verwendete Biogasmenge (Fackel):.................. m3

davon ca. 1'000 m3/d aus Bioabfall

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a / **N**ein

falls ja::

CH4 :	60	% vol
CO2 :	40	% vol
H2S :	………..	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : **Ja**

falls ja, Speichergrösse : 1'000 m3

Typ :
- ☐ Foliengasspeicher
- ☐ Wassertassengasometer
- X Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a

falls ja: Gaszusammensetzung nach Reinigung

CH4 :	60	% vol
CO2 :	40	% vol
H2S :	………..	ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :
- ☐ Nasswäscher: **W**asser / **org.** Lösungsmittel
- ☐ Aktivkohle
- ☐ Membran
- X Andere

Electricity Production **J**a

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell

- Total installed power : 480 kWel.

- Number of generators : 4

- Gross electricity production : 2.2 Mio. kWh

- Utilization of produced electricity :

Sale to third party	10 %	kWh
Self-consumption	90 %	kWh

Heat Production **J**a

- Type of heat production :
  - X Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - ☐ Heat from CHP
  - ☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : ca. 4 Mio. kWh

- Utilization of produced heat :

Sale to third party	-	kWh
Self-consumption	100 %	kWh

Other Utilization of the Biogas **Yes**

- ☐ N Injection into the gas grid
- ☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (DM)
Gross Investment Cost	5.2 Mio.
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (DM)
Electricity	5.0 / kWh
Heat	5.0/ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:..........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (DM)
Per Ton	ca. 200.--/t

Success and failures

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name		Stadt Karlsruhe	
Street		Ottostrasse 21	
Town		D-76227 Karlsruhe	
Country		CH-6340 Baar	
Telefone		0049 721 133-0	
Fax :		0049 721 133 70-09	
E-mail :			
Contact Person			
Name		Herr Boos	
Function			
Status	☐ Public ☐ Private ☐ Other : ……	X Public ☐ Private ☐ Other : ……	

Various Information

Reasons for the Choice of the System

- ☐ Energy Production
- ☐ Production of Compost
- ☐ Reduction of Waste Volume or Weight
- ☐ Reduction of the Organic Fraction
- ☐ Marketing/PR
- ☐ Subsidies as a Driver
- ☐ Rentability as compared to other Processes
- ☐ Other

Surface required for treatment

m2

Construction time

Start of construction:

Start-up of plant: 1997

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Dechets menages			…………………	…………………
Type	Marché			…………………	…………………
Amount per Year (in tons or m3)	8'000 t/y		…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	X			☐	☐
Size reduction	☐	☐	☐	☐	☐
Aerobic pre-treatment	☐	☐	☐	☐	☐
Hygienization	☐	☐	☐	☐	☐
Dehydration	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Other	☐ siehe Orign.	☐ ………	☐ ………	☐ ………	☐ ………
Composition					
DM-content	40 % od ……..… g/l	% od ……..… g/l	0 % od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
VS-content	% od ……..… g/l	% od ……..… g/l	% od ……..… g/l	……..… % od ……..… g/l	……..… % od. ……..… g/l
COD	40-43.5 g/l	……..… g/l	……..… g/l	……..… g/l	……..… g/l
Is the input material weighed at the gate	**Yes/No**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	☐ Flocculation
☐ Sedimentation Tank	X Composting	☐ Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	☐ Biological treatment
☐ Other :……………………	☐ Other:………………	X Other: STEP/Recirculation
☐ None	☐ None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	t or…….... ……..… m³	t or ……..… m³	9'000 t or ……..… m³	……..… t or ……..… m³
Is the amount estimated or measured?	Yes/No	Yes/No	Yes/No	Yes/No
Composition				
DM-content	% or…….. ……..… g/l	% or ……..… g/l	% or 6.9 g/l	……..… % or ……..… g/l
VS-content	% or ……..… g/l	% or ……..… g/l	% or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	4'460 -5'800 g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	X	☐	☐
Waste water treatment plant	☐	☐	X	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:	☐ ……………..	☐ ……………..	X Recirculation	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐………………….	☐………………….	☐………………….	☐………………….
a label product	☐………………….	☐………………….	☐………………….	☐………………….
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	1
Volume of each digester	.... / .... /1'350 m^3
Input Material	
Consistency	[x] Solid (> 15% TS) [ ] Liquid (=< 15% TS)
Maximum diameter	.... mm
Type of digester	
Operation	**Batch** / **Continuous**
Digestion temperature	35 °C
Make & Type of digester	MAT / BMA
Provider	MAT / BMA
Internal or external heat exchanger	Yes / No
Mixing	
Mixing with compressed biogas	[ ]
Mechanical Stirrer	[ ]
Hydraulic stirring	X
Other	[ ] ....
None	[ ]

Remarks

Double Stage Digestion

Digestion	First Stage Type of Digester 1	Intermediate Treatment (Please describe)	Second Stage Type of Digester 2
Dimensioning			
Number of digesters	....		…………………
Volume of each digester	……/………/ .... m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	30 mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	.... °C		.... °C
Make/type of digester	....		……………..
Provider	....		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ………………...........		☐ ………………...........
None	☐		☐

Remarks

Biogas Utilization

Jährliche Energiebilanz

Brutto Biogas-Produktion: 876'000 m3 Nicht verwendete Biogasmenge (Fackel): m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : **J**a / **N**ein

falls ja::

CH_4 : 60 % vol

CO_2 : % vol

H_2S : ……….. ppm

Andere : ……….. ……….. ppm

- Gibt es einen Gasspeicher ? : **J**a / **N**ein

falls ja, Speichergrösse : 900 m3

Typ : ☐ Foliengasspeicher

☐ Wassertassengasometer

☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : **J**a / **N**ein

falls ja: Gaszusammensetzung nach Reinigung

CH_4 : .... % vol

CO_2 : .... % vo

H_2S : ……….. ppm

Andere : ……….. ……….. ppm

Art der Biogas-Aufbereitung :

☐ Nasswäscher: **W**asser / **org.** Lösungsmittel

☐ Aktivkohle

☐ Membran

☐ Andere:

Electricity Production **Yes/No**

- Type of electricity production :

☐ CHP

☐ Gas turbine

X Steam turbine

☐ Fuel Cell

- Total installed power : ....kWel.

- Number of generators :

- Gross electricity production : .... kWh

- Utilization of produced electricity :

Sale to third party .... kWh

Self-consumption .... kWh

Heat Production **Yes/No**

- Type of heat production :

☐ Boiler: Steam

☐ Air heat exchanger

☐ Heat from CHP

☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : .... kWh

- Utilization of produced heat :

Sale to third party .... kWh

Self-consumption .... kWh

Other Utilization of the Biogas **Yes / No**

☐ Injection into the gas grid: m3/a

☐ Fuel :……………….……….m3/a

Remarks

Economy

Investment Cost

	Amount
Gross Investment Cost Fermentation + Composting	....
thereof subsidies	....
thereof auto-construction (cost savings)	
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount
Electricity	.... / kWh
Heat	.... / kWh
Other utilization of biogas	.... /kWh or /m3
Digestate/Composte	…………/t or /m3
Gate fees	
Substrate 1 :………………..	…………/t or /m3
Substrate 2 :…………………..	…………/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount
Operation and maintenance; if possible: - labor cost	
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount
Per Ton	

Success and failures

VEGAS

General Information

	OWNER	OPERATOR	PLANT PROVIDER
Address			
Name	VEGAS AG	VEGAS AG	Alpha Umwelttechnik AG
Street	Alte Lyss-Strasse 31	Alte Lyss-Strasse 31	Schloss-Strasse 15
Town	3270 Aarberg	3270 Aarberg	2560 Nidau
Country	Switzerland	Switzerland	Switzerland
Telefone	+41 32 392 47 74	+41 32 392 47 74	+41 32 331 54 54
Fax :	+41 32 392 47 75	+41 32 392 47 75	+41 32 331 23 37
E-mail :	info@oekostrom.ch	info@oekostrom.ch	
Contact Person			
Name		Andreas Utiger	
Function			
Status	☐ Public X Private ☐ Other : ……	☐ Public X Private ☐ Other : : ………	

Various Information

Reasons for the Choice of the System

x	Energy Production
x	Production of Compost
x	Reduction of Waste Volume or Weight
x	Reduction of the Organic Fraction
x	Marketing/PR
x	Subsidies as a Driver
……	Rentability as compared to other Processes
……	Other

Surface required for treatment

5'000 m2

Construction time

Start of construction: 1996

Start-up of plant: 1997

Remarks

Description of the Main Substrates

SUBSTRAT	Substrate n°1	Substrate n°2	Substrate n°3	Substrate n°4	Average Composition
Characterization					
Origin	Grüngut aus	Industrial Waste	…………………	…………………	…………………
Type	Haushalt + Garten	Food	…………………	…………………	…………………
Amount per Year (in tons or m3)	…………………	…………………	…………………	…………………	…………………
Pre-treatment					
Sieving/Separation	X partial				
Size reduction	X				
Aerobic pre-treatment					
Hygienization					
Dehydration					
None		X			
Other	………	………	………	………	………
Composition					
DM-content	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
VS-content	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od ……..…. g/l	……..…. % od. ……..…. g/l
COD	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l	……..…. g/l
Is the input material weighed at the gate	**Yes**				
Remarks					

Upgrading and Utilization of the Digestate

Upgrading Digestate	Upgrading Solid Phase	Upgrading Liquid Phase
☐ Press	☐ Drying	X Flocculation
☐ Sedimentation Tank	☐ Composting	X Centrifugation
☐ Centrifugation	☐ Size reduction	☐ Filtration
☐ Hygienization	☐ Sieving	X Biological treatment
☐ Other :……………………	☐ Other:………………	☐ Other:………………
☐ None	X None	☐ None

	Digestate	Solid Phase	Liquid Phase	Remaining Fraction
Quantity				
Quantity per year	……..… t or…….. ……..… m^3	6'000 t or ……..… m^3	5'000 t or ……..… m^3	100 t or ……..… m^3
Is the amount estimated or measured?	Yes/No	Yes/No	Yes/No	No
Composition				
DM-content	……..… % or…….. ……..… g/l	……..… % or ……..… g/l	……..… % or……..… g/l	……..… % or ……..… g/l
VS-content	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l	……..… % or ……..… g/l
COD	……..… mg/l	……..… mg/l	……..… g/l	……..… g/l
Utilization of digestate				
Agricultural Application	☐	☐	☐	☐
Waste water treatment plant	☐	☐	☐	☐
Landfill	☐	☐	☐	☐
Incineration	☐	☐	☐	☐
Other:...............................	☐ ……………..	☐ ……………..	☐ ……………..	☐ ……………..
Product Quality				
The product corresponds to				
a legal requirement	☐....................	X yes....................	X yes....................	X yes....................
a label product	☐....................	☐....................	☐....................	☐....................
Other	…………………	…………………	…………………	…………………
Remarks				

Single Stage Digestion

Digestion	**Digester(s)**
Dimensioning	
Number of digesters	1
Volume of each digester	……/………/ 1'500 m^3
Input Material	
Consistency	X Solid (> 15% TS) ☐ Liquid (=< 15% TS)
Maximum diameter	40. mm
Type of digester	
Operation	**Continuous**
Digestion temperature	55 °C
Make & Type of digester	agritechnica
Provider	agritechnica
Internal or external heat exchanger	no
Mixing	
Mixing with compressed biogas	☐
Mechanical Stirrer	☐
Hydraulic stirring	☐
Other	☐ ……………..........
None	X

Remarks

Double Stage Digestion

Digestion	**First Stage** **Type of Digester 1**	**Intermediate Treatment** **(Please describe)**	**Second Stage** **Type of Digester 2**
Dimensioning			
Number of digesters	…………………		…………………
Volume of each digester	……/………/…… m^3		……/………/…… m^3
Input Material			
Consistency	Solid (> 15% TS) Liquid (=< 15% TS)		Solid (> 15% TS) Liquid (=< 15% TS)
Maximum diameter	…………….. mm	Quantity entering second stage	…………….. mm
Type of Digester		……......…m3	
Operation	**B**atch /**C**ontinuous	or ……………t	**B**atch / **Continuous**
Digestion temperature	………………… °C		………………… °C
Make/type of digester	……………..		……………..
Provider	…………………		…………………
External heat exchanger	**Yes/No**		**Yes/No**
Mixing			
Mixing with compressed biogas	☐		☐
Mechanical stirrers	☐		☐
Hydraulic mixing	☐		☐
Other	☐ ……………..........		☐ ……………..........
None	☐		☐

Remarks

Biogas Utilization

Järliche Energiebilanz

Brutto Biogas-Produktion: 810'000 m3 | Nicht verwendete Biogasmenge (Fackel): 50'000 m3

Roh-Biogas

- Wird die Gaszusammensetzung analysiert : Ja

falls ja::

CH_4 :	40-60	% vol
CO_2 :	………..	% vol
H_2S :	………..	ppm
Andere : ………..	………..	ppm

- Gibt es einen Gasspeicher ? : **Ja**

falls ja, Speichergrösse : 380 m3

Typ :
- X Foliengasspeicher
- ☐ Wassertassengasometer
- ☐ Andere : ………..

Biogas reinigung

- Wird das Biogas aufbereitet? : Ja

falls ja: Gaszusammensetzung nach Reinigung

CH_4 :	40-60	% vol
CO_2 :	………..	% vol
H_2S :	………...	ppm
Andere : ………..	………..	ppm

Art der Biogas-Aufbereitung :
- X Nasswäscher: Wasser
- ☐ Aktivkohle
- ☐ Membran
- ☐ Andere

Electricity Production **Yes**

- Type of electricity production :
  - X CHP
  - ☐ Gas turbine
  - ☐ Steam turbine
  - ☐ Fuel Cell

- Total installed power : 495 kWel.

- Number of generators : 1

- Gross electricity production : 1'070'000 kWh

- Utilization of produced electricity :

Sale to third party	570'000	kWh
Self-consumption	570'000	kWh

Heat Production **Yes/No**

- Type of heat production :
  - X Boiler: Steam/Heat
  - ☐ Air heat exchanger
  - ☐ Heat from CHP
  - ☐ Other : ……………………

- Total installed power : .... kWth.

- Gross heat production : …………….. kWh

- Utilization of produced heat :

Sale to third party	…………….. kWh
Self-consumption	…………….. kWh

Other Utilization of the Biogas **No**

- ☐ N Injection into the gas grid
- ☐ Fuel :………………………..m3/a

Remarks

Economy

Investment Cost

	Amount (Unit)
Gross Investment Cost	ca. 14 Mio.
thereof subsidies	…………………..
thereof auto-construction (cost savings)	....
Part of Plant	
Digester(s)	....
Upgrading and utilization of biogas	....
Other	………………..

Income

	Amount (Unit)
Electricity	1'070'000 / kWh
Heat	…………../ kWh
Other utilization of biogas	…………/kWh or /m3
Digestate/Composte	6'000/t
Gate fees	
Substrate 1 : Grüngut aus Haushalt und Garten	10'000/t or /m3
Substrate 2 :Industrial waste and food	1'000/t or /m3
Substrate 3 : …………………..	…………/t or /m3
General Tipping fees	…………/t or /m3
Subsidies/Tax money	....
Other:...........................	....

Operation Cost

	Amount (Unit)
Operation and maintenance; if possible: - labor cost	....
maintenance cost	
Capital cost	....
Other	....

Total treatment cost

	Amount (Unit)
Per Ton	………………

Success and failures

Appendix C

Organic Waste Generator Survey and Cover Letters

Re: Landmark Study on Anaerobic Digestion – Survey of Linn County Businesses

Dear Linn County Business Leaders:

Bluestem Solid Waste Agency is conducting a landmark study of the technical and economic feasibility of anaerobic digestion (AD) as a waste management technology. It is one of the first studies of its kind to be undertaken in the United States. However, AD is a mature technology first used in larger wastewater treatment plants in the mid-1800's. In the early 1990's, successful adaptations of the technology to solid waste began to appear, primarily in Europe. AD is a higher technology requiring substantial investment but is considerably less expensive than incineration. The main by-products of AD are methane (as a fuel source) and compost. A relatively small amount of material from biodegradable waste is rejected and landfilled.

To help you gauge the scope of the study, the following short list is offered. Bluestem is attempting to determine the following:

- Where anaerobic digestion of waste has been successfully used;
- If AD can be used to manage a portion of Bluestem's waste stream;
- What are the impacts of adding AD to our management system;
- What are the short and long-term costs; and
- What potential technical or administrative barriers may exist.

Bluestem, in a joint cooperative investigation with the Iowa Department of Natural Resources, has retained R. W. Beck, Inc., Minneapolis, to conduct this study. R. W. Beck has a successful and strong history in solid waste management and has previously done work for both Bluestem and the Department of Natural Resources. Bluestem is very confident that R. W. Beck will provide a quality analysis with high value recommendations. A survey requesting the necessary information will be coming to you within the next two weeks from R. W. Beck. **We respectfully request that you give the survey your fullest attention and priority.**

In addition to Bluestem's interest, the Best Practices Roundtable (Roundtable), an association of local industry environmental and technical experts, has endorsed this feasibility study. It is now becoming clear that Linn County faces some of the most serious solid waste challenges of any highly successful commercial/industrial center in the Midwest. The Roundtable has pledged its support in providing information and assisting others with any questions they may have regarding solid waste issues or this survey.

Information provided in response to the survey will be reported in aggregate form, not on a company-specific basis. If there are additional confidentiality needs associated with certain information, R. W. Beck will work with you to address your needs. Bluestem staff will also be available to assist in any way feasible, including answering any questions. Thank you very much for your participation in this important study.

Bluestem Solid Waste Agency,

CC: Robert Craggs, R. W. Beck, Inc.

Date

Contact
Org. name
Address
City, State, Zip

Dear (contact name) or Environmental Manager:

Recently you should have received a letter from the Bluestem Solid Waste Agency informing you of the Anaerobic Digestion Feasibility Study. Bluestem, in a joint cooperative investigation with the Iowa Department of Natural Resources, has retained R.W. Beck, Inc., Minneapolis, to conduct this study.

We are asking you and other Linn County business leaders to help us with this important study by completing the enclosed Solid Waste and Organics survey. The survey will provide us with an estimate of the amount and composition of solid and organic waste produced in Linn County. All information provided in response to the survey will be reported in an aggregate form, not on a company-specific basis. The results of the survey process will allow us to assess the feasibility of using anaerobic digestion to manage a portion of Bluestem's waste stream.

We appreciate your participation in this landmark study and thank you in advance for completing the enclosed survey. You may fax your completed survey to (651) 994-8396, attention Mary Chamberlain; mail the completed survey to: Mary Chamberlain, R. W. Beck, Inc., 1380 Corporate Center Curve, Suite 305, St. Paul, MN 55121; or complete the survey electronically by going to: www.rwbeck.com/bluestem.

Please respond by December 21, 2001. If you have any questions regarding the survey, please contact Mary Chamberlain at (651) 994-8415 or mchamberlain@rwbeck.com, or Karmin Bradbury at Bluestem Solid Waste Agency at (319) 398-1278 or kbradbury@bluestem.org.

Thank you again for your valuable contribution.

Sincerely,

Bluestem Solid Waste Agency

Anaerobic Digestion Feasibility Study

Solid Waste and Organics Survey
Industrial, Commercial, and Institutional Generators

This survey may also be completed on-line at: www.rwbeck.com/bluestem. *The information you provide will automatically be entered into a private database and will not be accessible or viewed by others.*

Company Name:	
Street Address:	
City, State, Zip Code:	
Telephone Number:	
Fax Number:	
E-mail address:	
Contact Person:	

1. How much total solid waste[1] has your facility produced in the last two years?

   2000: ____________________ ☐ cubic yards or ☐ tons

   1999: ____________________ ☐ cubic yards or ☐ tons

   Were these amounts based on:

   ☐ actual measurements

   ☐ estimates

[1] Garbage, refuse, rubbish, and other similar discarded solid or semisolid materials, including, but not limited to, such materials resulting from industrial, commercial, agricultural, and domestic activities, including sludges.

2. Do you anticipate any increase or decrease in the quantity of solid waste produced at your facility or facilities in the next 1 to 3 years?

   ☐ Yes   ☐ No

   If yes, how much?

   ☐ Increase by __________% annually

   ☐ Decrease by __________% annually

3. How does your firm currently handle waste collection and disposal?

   ☐ Waste is collected by a private hauler.

   ☐ Waste is delivered to a disposal site by our company.

   ☐ Other: ____

4. In order to determine if anaerobic digestion would be financially feasible, the current cost of solid waste collection and disposal needs to be analyzed to compare overall costs for an alternative system. This is the basis for the following inquiry: What is your average **annual** and per unit cost for solid waste services or removal (monthly refuse rates, dumpster fees, etc.)? Please provide per ton or cubic yard costs, if available.

   $ __________________ Total annual costs

   $ __________________ ☐ per ton ☐ per cubic yard

5. Where is your solid waste currently managed?

   ☐ Site 1 (former Cedar Rapids Landfill)

   ☐ Site 2 (former Linn County Landfill)

   ☐ BFC (incinerator)

   ☐ Other: ____

6. What percentage of your waste stream is estimated to be organic or compostable waste (i.e., food waste, soiled paper, mixed paper, yard waste, sludges, spillage, etc.)?

   _____________ % (or _____________ cubic yards or _____________ tons)

   a. What type of materials make up your organics waste stream?

b. Does your facility currently divert the organic waste from disposal for recycling and/or re-use?

☐ Yes. Organic waste is taken to ________________________ for ________________ (use).

☐ No.

If yes, what percentage of your organic waste is currently being diverted?

____________ % (or ____________ cubic yards or ____________ tons)

c. Do you transport the organic waste to the end-user or is it transported by a hauler?

☐ Organic waste is transported by a private hauler.

☐ Organic waste is delivered to a disposal site by our company.

☐ Other: ____

d. Are you paid for the organic waste? If so, how much revenue (per ton or cubic yard) is generated from the sale of organic waste? If not, how much do you pay to divert the organic waste?

☐ Yes. We are paid $ _______________ ☐ per ton ☐ per cubic yard

☐ No. We pay $ ___________________ ☐ per ton ☐ per cubic yard

☐ No payment is made for transportation costs, but no revenue is received.

7. If you generate organic waste, but don't separate it from the waste stream, what are the barriers to overcome for you and your company to separate the organic waste for processing or re-use?

8. If Bluestem Solid Waste Agency developed a technique to recycle and/or re-use organic material, would you be willing to source separate these organic materials for re-use?

☐ Yes ☐ No

Would you be willing to transport the source-separated organics to a Bluestem processing facility?

☐ Yes ☐ No

Please take the time to complete the table on the following page. Thank you for your cooperation.

Solid Waste[1] and Organics Survey **Industrial, Commercial, and Institutional Generators**		
	Waste Generated[2] in 2000	**Waste Recycled/Composted in 2000**
Type of Waste	**Tons per Year, Cubic Yards per Year or % of Total Waste Stream**	**Tons per Year, Cubic Yards per Year or % of Total Waste Stream**
EXAMPLE: Newsprint	*30% of total waste stream or 20 Tons*	*100% recycled or 20 Tons*
Paper		
Corrugated Cardboard		
Newsprint		
Office Grade		
Other/Mixed		
Wood		
Pallets		
Other:		
Organics		
Food		
Yard Waste[3]		
Sludges		
Other:		
Fabric/Cloth		
Other Organic Wastes:		
All Other Non-Organic Waste:		
TOTALS[4]:		

[1] Garbage, refuse, rubbish, and other similar discarded solid or semisolid materials, including, but not limited to, such materials resulting from industrial, commercial, agricultural, and domestic activities, including sludges.
[2] Amount prior to recycling or composting.
[3] Vegetative matter such as grass clippings, leaves, garden waste, brush, and trees. Yard waste does not include tree stumps.
[4] Total waste generated in 2000 should equal total in Question 1.

Results will be released *only* in aggregate form, no company-specific information will be reported.

Please forward the completed survey to: Mary Chamberlain, R. W. Beck, Inc., 1380 Corporate Center Curve, Suite 305, St. Paul, MN 55121 or via facsimile to: (651) 994-8396, attention Mary Chamberlain, or you may access the survey by going to: www.rwbeck.com/bluestem. If you have any questions related to this survey, please contact Mary at (651) 994-8415.

Thank you in advance for taking the time to complete this survey.

Appendix D

List of Organic Waste Generators Surveyed

Appendix D
List of Organic Waste Generators Surveyed

Dean Frommett
ADM
1350 Waconia Av SW
Cedar Rapids, IA 52404

Marilyn Atkinson
Alliant Engergy
200 1st St SE
Cedar Rapids, IA 52401

Evironmental Manager
Apache Hose & Belting
4805 Bowling St SW
Cedar Rapids, IA 52404

Evironmental Manager
Ar-Jay Building Products
1515 Blairs Ferry Rd NE
Cedar Rapids, IA 52402

Dean Ahrens
Cargill, Inc.
1010 10th Avenue SW
Cedar Rapids, IA 52404

Evironmental Manager
CCB Packaging
1905 N Center Point Rd
Hiawatha, IA 52233

Tom Berg
Cedar River Paper Company
PO Box 3250
Cedar Rapids, IA 52406-3250

Evironmental Manager
Cedarapids, Inc.
916 16 St NE
Cedar Rapids, IA 52402

Evironmental Manager
CEI Equipment Company
5555 16 Av SW
Cedar Rapids, IA 52404

Evironmental Manager
Coe College
1220 1st Av NE
Cedar Rapids, IA 52402

Glen Dodd
Cornell College
600 1st Street W
Mount Vernon, IA 52314

Evironmental Manager
Cryovac
PO Box 1167
Cedar Rapids, IA 52404

Jim Prohaska
Diamond V Mills
838 1 St NW
Cedar Rapids, IA 52401

John Wodnik
Evergreen Packaging
2400 6th St SW
Cedar Rapids, IA 52404

Evironmental Manager
Food Waste Solutions
3854 Buffalo Ridge Road
Anamosa, IA 52205

Evironmental Manager
Gazette Company
500 3rd Avenue SE
Cedar Rapids, IA 52401

Iris Vering
Genencor International
1000 41st Av Dr SW
Cedar Rapids, IA 52404

Arthur Potratz
General Mills
PO Box 3007
Cedar Rapids, IA 52406

Evironmental Manager
Hamiliton
1924 D Street
Cedar Rapids, IA 52404

Evironmental Manager
Highway Equipment Company
616 D Ave NW
Cedar Rapids, IA 52405

Evironmental Manager
Hunter's Specialties
600 Huntington Ct NE
Cedar Rapids, IA 52402

Evironmental Manager
Iowa Precision Industries
5480 6 St SW
Cedar Rapids, IA 52404

Doug Elam
Kirkwood Community College
6301 Kirkwood Blvd SW
Cedar Rapids, IA 52404

Evironmental Manager
Lindale Mall
4444 1st Av NE
Cedar Rapids, IA 52404

Evironmental Manager
Longview Fibre
1601 Blairs Ferry Rd NE
Cedar Rapids, IA 52402

Evironmental Manager
MAAX Midwest
4601 8th Av
Marion, IA 52302

Evironmental Manager
McLeodUSA
6400 C Street SW
Cedar Rapids, IA 52404

Appendix D
List of Organic Waste Generators Surveyed

John Miller
Mercy Hospital
701 10th St SE
Cedar Rapids, IA 52403

Evironmental Manager
Mount Mercy
1330 Elmhusrt Dr NE
Cedar Rapids, IA 52402

Evironmental Manager
MSI Moldbuilders
12300 6th St SW
Cedar Rapids, IA 52404

Evironmental Manager
Nash Finch Company
1201 Blairs Ferry Rd NE
Cedar Rapids, IA 52402

Evironmental Manager
Norwood Inc.
202 F Av NW
Cedar Rapids, IA 52405

Otto Rajtora
Penford
PO Box 428
Cedar Rapids, IA 52406

Walt Corey
Pickwick Mfg.
1870 McCloud Pl NE
Cedar Rapids, IA 52402

Dan Shulgin
Pillsbury
1000 Wenig Rd NE
Cedar Rapids, IA 52402

John Gordon
PMX
5300 Willow Creek Drive SW
Cedar Rapids, IA 52404

Will Carew
Quaker Oats
PO Box 1848
Cedar Rapids, IA 52406

Jaime Ashby
Quality Chef Foods
1100 3 St SE
Cedar Rapids, IA 52401

Evironmental Manager
Ralston Foods
601 16th St NE
Cedar Rapids, IA 52402

Evironmental Manager
ReVosWel
320 35th St
Marion, IA 52302

Darrel Brotherson
Rockwell Collins
855 35th Street NE
Cedar Rapids, IA 52498

Jim Jensen
Square D Company
3700 6th St SW
Cedar Rapids, IA 52404

Annette Wolter
St. Lukes
PO Box 3026
Cedar Rapids, IA 52406

Evironmental Manager
Svedala Industries
800 1 Av NW
Cedar Rapids, IA 52405

Wayne Scott
Vigortone Ag
5264 Council Street NE
Cedar Rapids, IA 52402

Evironmental Manager
Westdale Mall
2600 Edgewood Rd SW
Cedar Rapids, IA 52404

Daron May
Weyerhaeuser
PO Box 3250
Cedar Rapids, IA 52406

Environmental Manager
Wholesale Feeds
6000 Linn Aire Av
Marion, IA 52302

Appendix E

Facility Cost Analysis – Supplement Cost Tables

Materials Flow

	Site 1					Site 2				
		Compost								Combined
Month	Landfilled	(Yard Waste)	Recycled	Sludges	Total	Landfilled	Bioreactor	Recycled	Total	Total
Jul-01	9,686	1,871	1,859	5,059	18,476	4,764	-	424	5,188	23,664
Aug-01	11,929	1,957	2,574	4,048	20,508	5,246	-	428	5,674	26,182
Sep-01	12,954	1,683	2,576	2,597	19,811	4,576	-	415	4,990	24,801
Oct-01	10,297	175	3,148	5,578	19,199	4,461	-	436	4,897	24,096
Nov-01	8,791	2,432	2,031	5,458	18,712	4,762	-	455	5,216	23,928
Dec-01	8,316	944	1,070	4,378	14,708	4,106	-	501	4,608	19,316
Jan-02	8,618	752	685	5,685	15,740	3,305	-	434	3,739	19,479
Feb-02	7,635	589	563	3,818	12,605	2,816	-	333	3,148	15,753
Mar-02	8,680	1,357	1,071	5,133	16,241	2,810	-	382	3,193	19,434
Apr-02	10,377	2,267	1,477	7,558	21,678	4,381	-	530	4,911	26,589
May-02	12,335	3,282	651	8,334	24,602	4,626	-	573	5,199	29,801
Jun-02	11,659	2,811	842	5,864	21,177	5,064	-	538	5,602	26,778
Total	***121,278***	***20,121***	***18,547***	***63,511***	***223,457***	***50,915***	***-***	***5,449***	***56,364***	***279,821***

				% of
Summary	Current	Adjustements	Revised	Wastestream
Landfilled	172,193	-	172,193	58%
Compost	20,121	63,511	83,632	28%
Recycled	23,996	14,689	38,685	13%
Sludges	63,511	(63,511)	-	0%
AD	-	-	-	0%
Total	279,821		294,510	100%

Materials and Energy Projections

Material		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Landfilled	tons	172,193	177,359	182,680	188,160	193,805	199,619	205,608	211,776	218,129	224,673	231,413	238,356	245,506	252,872	260,458	268,271	276,320	284,609	293,147	301,942	311,000
Compost	tons	83,632	86,141	88,725	91,387	94,128	96,952	99,861	102,857	105,942	109,121	112,394	115,766	119,239	122,816	126,501	130,296	134,205	138,231	142,378	146,649	151,049
Recycled	tons	38,685	39,845	41,041	42,272	43,540	44,846	46,192	47,577	49,005	50,475	51,989	53,549	55,155	56,810	58,514	60,270	62,078	63,940	65,858	67,834	69,869
Sludges	tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AD	tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	tons	294,510	303,345	312,446	321,819	331,473	341,418	351,660	362,210	373,076	384,269	395,797	407,671	419,901	432,498	445,473	458,837	472,602	486,780	501,383	516,425	531,918
Electricity Generated	MWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rates																						
MSW	$/ton	36.00	36.36	36.72	37.09	37.46	37.84	38.21	38.60	38.98	39.37	39.77	40.16	40.57	40.97	41.38	41.79	42.21	42.63	43.06	43.49	43.93
Compost	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Sludge	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Electricity	cents/kWh	4.2	4.24	4.28	4.33	4.37	4.41	4.46	4.50	4.55	4.59	4.64	4.69	4.73	4.78	4.83	4.88	4.92	4.97	5.02	5.07	5.12
Revenues																						
MSW	$000	6,199	6,449	6,709	6,979	7,260	7,553	7,857	8,174	8,503	8,846	9,202	9,573	9,959	10,360	10,778	11,212	11,664	12,134	12,623	13,132	13,661
Compost/Sludge	$000	1,254	1,305	1,358	1,412	1,469	1,528	1,590	1,654	1,721	1,790	1,862	1,937	2,015	2,097	2,181	2,269	2,361	2,456	2,555	2,658	2,765
Electricity	$000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	$000	7,453	7,754	8,066	8,391	8,730	9,081	9,447	9,828	10,224	10,636	11,065	11,511	11,975	12,457	12,959	13,481	14,025	14,590	15,178	15,790	16,426

Annual Growth Rates		
Total Waste Stream	%	3%
MSW Tip Fee	%	1%
Compost/Sludge Tip Fee	%	1%
Electricity Sales Rate	%	1%

Electrical Generation		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Biogas Production	MMBtu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tons of Feedstock/Year	tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feedstock to kWh Conversion Rate		4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Annual MWh Parasitic Ele	MWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GenSet Converstion Effec	%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%
Btu/kWh Conversion Rate		3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413
Capacity Factor	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Gross kWh Produced	MWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net kWh Produced	MWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Materials and Energy Projections

(con't)

Material		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Landfilled	tons	154,129	158,753	163,516	168,421	173,474	178,678	184,038	189,559	195,246	201,104	207,137	213,351	219,751	226,344	233,134	240,128	247,332	254,752	262,395	270,266	278,374
Compost	tons	65,568	67,535	69,561	71,648	73,797	76,011	78,292	80,640	83,059	85,551	88,118	90,761	93,484	96,289	99,177	102,153	105,217	108,374	111,625	114,974	118,423
Recycled	tons	38,685	39,845	41,041	42,272	43,540	44,846	46,192	47,577	49,005	50,475	51,989	53,549	55,155	56,810	58,514	60,270	62,078	63,940	65,858	67,834	69,869
Sludges	tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AD	tons	36,128	37,212	38,328	39,478	40,662	41,882	43,139	44,433	45,766	47,139	48,553	50,010	51,510	53,055	54,647	56,286	57,975	59,714	61,506	63,351	65,251
Total	tons	294,510	303,345	312,446	321,819	331,473	341,418	351,660	362,210	373,076	384,269	395,797	407,671	419,901	432,498	445,473	458,837	472,602	486,780	501,383	516,425	531,918
Electricity Generated	MWh	4,393	4,525	4,660	4,800	4,944	5,092	5,245	5,403	5,565	5,732	5,904	6,081	6,263	6,451	6,645	6,844	7,049	7,261	7,478	7,703	7,934
Rates																						
MSW	$/ton	36.00	36.36	36.72	37.09	37.46	37.84	38.21	38.60	38.98	39.37	39.77	40.16	40.57	40.97	41.38	41.79	42.21	42.63	43.06	43.49	43.93
Compost	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Sludge	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Electricity	cents/kWh	4.2	4.24	4.28	4.33	4.37	4.41	4.46	4.50	4.55	4.59	4.64	4.69	4.73	4.78	4.83	4.88	4.92	4.97	5.02	5.07	5.12
Revenues																						
MSW	$000	5,549	5,772	6,005	6,247	6,499	6,761	7,033	7,316	7,611	7,918	8,237	8,569	8,914	9,274	9,647	10,036	10,441	10,861	11,299	11,754	12,228
Compost/Sludge	$000	984	1,023	1,064	1,107	1,152	1,198	1,247	1,297	1,349	1,404	1,460	1,519	1,580	1,644	1,710	1,779	1,851	1,925	2,003	2,084	2,167
Electricity	$000	184	192	200	208	216	225	234	243	253	263	274	285	296	308	321	334	347	361	376	391	407
Total	$000	6,717	6,987	7,269	7,562	7,867	8,184	8,513	8,857	9,213	9,585	9,971	10,373	10,791	11,226	11,678	12,149	12,638	13,148	13,678	14,229	14,802

Annual Growth Rates		
Total Waste Stream	%	3%
MSW Tip Fee	%	1%
Compost/Sludge Tip Fee	%	1%
Electricity Sales Rate	%	1%

Electrical Generation		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Biogas Production	MMBtu	49,318	50,798	52,322	53,891	55,508	57,173	58,889	60,655	62,475	64,349	66,280	68,268	70,316	72,426	74,598	76,836	79,141	81,516	83,961	86,480	89,074
Tons of Feedstock/Year	tons	36,128	37,212	38,328	39,478	40,662	41,882	43,139	44,433	45,766	47,139	48,553	50,010	51,510	53,055	54,647	56,286	57,975	59,714	61,506	63,351	65,251
Feedstock to kWh Conversion Rate		4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Annual MWh Parasitic Electric	MWh	159	164	169	174	179	184	190	196	201	207	214	220	227	233	240	248	255	263	271	279	287
GenSet Converstion Effeciency	%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%
Btu/kWh Conversion Rate		3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413
Capacity Factor	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Gross kWh Produced	MWh	4,552	4,688	4,829	4,974	5,123	5,277	5,435	5,598	5,766	5,939	6,117	6,301	6,490	6,684	6,885	7,092	7,304	7,523	7,749	7,982	8,221
Net kWh Produced	MWh	4,393	4,525	4,660	4,800	4,944	5,092	5,245	5,403	5,565	5,732	5,904	6,081	6,263	6,451	6,645	6,844	7,049	7,261	7,478	7,703	7,934

AD Sources	
Landfill	50%
Sludges	50%
Recycling	0%

Materials and Energy Projections
(con't)

Material		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Landfilled	tons	137,713	141,845	146,100	150,483	154,997	159,647	164,437	169,370	174,451	179,684	185,075	190,627	196,346	202,236	208,304	214,553	220,989	227,619	234,447	241,481	248,725
Compost	tons	49,152	50,626	52,145	53,710	55,321	56,981	58,690	60,451	62,264	64,132	66,056	68,038	70,079	72,181	74,347	76,577	78,874	81,241	83,678	86,188	88,774
Recycled	tons	38,685	39,845	41,041	42,272	43,540	44,846	46,192	47,577	49,005	50,475	51,989	53,549	55,155	56,810	58,514	60,270	62,078	63,940	65,858	67,834	69,869
Sludges	tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AD	tons	68,960	71,029	73,160	75,354	77,615	79,944	82,342	84,812	87,356	89,977	92,676	95,457	98,320	101,270	104,308	107,437	110,661	113,980	117,400	120,922	124,549
Total	tons	294,510	303,345	312,446	321,819	331,473	341,418	351,660	362,210	373,076	384,269	395,797	407,671	419,901	432,498	445,473	458,837	472,602	486,780	501,383	516,425	531,918
Electricity Generated	MWh	7,876	8,112	8,356	8,606	8,865	9,131	9,405	9,687	9,977	10,277	10,585	10,902	11,229	11,566	11,913	12,271	12,639	13,018	13,409	13,811	14,225
Rates																						
MSW	$/ton	36.00	36.36	36.72	37.09	37.46	37.84	38.21	38.60	38.98	39.37	39.77	40.16	40.57	40.97	41.38	41.79	42.21	42.63	43.06	43.49	43.93
Compost	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Sludge	$/ton	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12	18.30
Electricity	cents/kWh	4.2	4.24	4.28	4.33	4.37	4.41	4.46	4.50	4.55	4.59	4.64	4.69	4.73	4.78	4.83	4.88	4.92	4.97	5.02	5.07	5.12
Revenues																						
MSW	$000	4,958	5,157	5,365	5,582	5,806	6,040	6,284	6,537	6,801	7,075	7,360	7,656	7,965	8,286	8,620	8,967	9,329	9,705	10,096	10,502	10,926
Compost/Sludge	$000	737	767	798	830	864	898	935	972	1,011	1,052	1,095	1,139	1,185	1,232	1,282	1,334	1,387	1,443	1,501	1,562	1,625
Electricity	$000	331	344	358	372	387	403	419	436	454	472	491	511	531	553	575	598	622	648	674	701	729
Total	$000	6,026	6,269	6,521	6,784	7,057	7,342	7,638	7,946	8,266	8,599	8,945	9,306	9,681	10,071	10,477	10,899	11,338	11,795	12,271	12,765	13,280
Electrical Generation																						
Annual Biogas Production	MMBtu	88,625	91,283	94,022	96,843	99,748	102,740	105,823	108,997	112,267	115,635	119,104	122,677	126,358	130,148	134,053	138,074	142,217	146,483	150,878	155,404	160,066
Tons of Feedstock/Year	tons	68,960	71,029	73,160	75,354	77,615	79,944	82,342	84,812	87,356	89,977	92,676	95,457	98,320	101,270	104,308	107,437	110,661	113,980	117,400	120,922	124,549
Feedstock to kWh Conversion Rate		4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Annual MWh Parasitic Electric	MWh	303	313	322	332	342	352	362	373	384	396	408	420	433	446	459	473	487	502	517	532	548
GenSet Converstion Effeciency	%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%
Btu/kWh Conversion Rate		3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413
Capacity Factor	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Gross kWh Produced	MWh	8,180	8,425	8,678	8,938	9,206	9,482	9,767	10,060	10,362	10,672	10,993	11,322	11,662	12,012	12,372	12,743	13,126	13,520	13,925	14,343	14,773
Net kWh Produced	MWh	7,876	8,112	8,356	8,606	8,865	9,131	9,405	9,687	9,977	10,277	10,585	10,902	11,229	11,566	11,913	12,271	12,639	13,018	13,409	13,811	14,225

Annual Growth Rates		
Total Waste Stream	%	3%
MSW Tip Fee	%	1%
Compost/Sludge Tip Fee	%	1%
Electricity Sales Rate	%	1%

AD Sources	
Landfill	50%
Sludges	50%
Recycling	0%

Bluestem Solid Waste Agency

Large AD Expected Present Value Analysi

			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
	Revenues																					
1	Electric Energy																					
2	Net kWh Available for Sale	(MWh)	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767	7,767
3	Energy Price [4]	(¢/kWh)	3.10	3.13	3.16	3.19	3.23	3.26	3.29	3.32	3.36	3.39	3.42	3.46	3.49	3.53	3.56	3.60	3.63	3.67	3.71	3.75
4	*Energy Revenues*	($000)	241	243	246	248	251	253	256	258	261	263	266	269	271	274	277	280	282	285	288	291
	Thermal Energy																					
5	Net Thermal Recovered [3]	(MMBtu)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Natural Gas Price [5]	($/MMBtu)	6.00	6.06	6.12	6.18	6.24	6.31	6.37	6.43	6.50	6.56	6.63	6.69	6.76	6.83	6.90	6.97	7.04	7.11	7.18	7.25
7	*Thermal Energy Revenues*	($000)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sludges Tip Fees																					
8	Sludges Per year [3]	(Tons)	32,364	33,335	34,335	35,365	36,426	37,519	38,644	39,804	40,998	42,228	43,495	44,799	46,143	47,528	48,953	50,422	51,935	53,493	55,098	56,750
9	Sludges Tip Fee [6]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
10	*Sludges Revenues*	($000)	485	505	525	547	569	591	615	640	666	693	721	750	780	811	844	878	913	950	989	1,028
	Other Organics Tip Fees																					
11	Organics [3]	(Tons)	33,300	34,299	35,328	36,388	37,479	38,604	39,762	40,955	42,183	43,449	44,752	46,095	47,478	48,902	50,369	51,880	53,437	55,040	56,691	58,392
12	Organics Tip Fee [7]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
13	*Organics Revenues*	($000)	500	520	541	562	585	609	633	659	685	713	742	771	802	835	868	903	940	978	1,017	1,058
	Food Waste Tip Fees																					
14	Food Waste [3]	(Tons)	2,934	3,022	3,113	3,206	3,302	3,401	3,503	3,608	3,717	3,828	3,943	4,061	4,183	4,309	4,438	4,571	4,708	4,849	4,995	5,145
15	Food Waste Tip Fee [8]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
16	*Food Waste Revenues*	($000)	44	46	48	50	52	54	56	58	60	63	65	68	71	74	77	80	83	86	90	93
	Yard Waste Tip Fees																					
17	Yard Waste [3]	(Tons)	362	373	384	396	407	420	432	445	459	472	486	501	516	532	548	564	581	598	616	635
18	Yard Waste Tip Fee [9]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
19	*Yard Waste Revenues*	($000)	5	6	6	6	6	7	7	7	7	8	8	8	9	9	9	10	10	11	11	12
20	*Total Revenues*	($000)	1,275	1,319	1,365	1,413	1,462	1,513	1,567	1,622	1,680	1,739	1,802	1,866	1,933	2,003	2,075	2,151	2,229	2,310	2,394	2,482
21	PV Total Revenues	($000)	1,275	1,306	1,338	1,371	1,405	1,440	1,476	1,513	1,551	1,590	1,631	1,673	1,716	1,760	1,805	1,852	1,901	1,950	2,002	2,055
	Expenses																					
	Fiber Hauling Costs																					
22	Fiber [3]	(Tons)	16,127	16,611	17,109	17,622	18,151	18,696	19,256	19,834	20,429	21,042	21,673	22,324	22,993	23,683	24,394	25,125	25,879	26,655	27,455	28,279
23	Fiber Hauling Cost Rate [1	($/Ton)	3.00	3.09	3.18	3.28	3.38	3.48	3.58	3.69	3.80	3.91	4.03	4.15	4.28	4.41	4.54	4.67	4.81	4.96	5.11	5.26
24	*Fiber Hauling Costs*	($000)	48	51	54	58	61	65	69	73	78	82	87	93	98	104	111	117	125	132	140	149
	Filtrate Pumping and Treatment Costs																					
25	Gallons of Filtrate [3]	(h Gal)	114,840	118,285	121,834	125,489	129,253	133,131	137,125	141,239	145,476	149,840	154,335	158,965	163,734	168,646	173,706	178,917	184,284	189,813	195,507	201,373
26	Filtrate Pumping Cost Rate [1	($/h Gal)	0.075	0.077	0.080	0.082	0.084	0.087	0.090	0.092	0.095	0.098	0.101	0.104	0.107	0.110	0.113	0.117	0.120	0.124	0.128	0.132
27	*Filtrate Pumping Costs*	($000)	9	9	10	10	11	12	12	13	14	15	16	17	18	19	20	21	22	24	25	26
	AD Unit Labor																					
28	Annual AD Unit hours	(Hrs)	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
29	Average AD Labor Rate [1	($/Hr)	17.80	18.33	18.88	19.45	20.03	20.64	21.25	21.89	22.55	23.22	23.92	24.64	25.38	26.14	26.92	27.73	28.56	29.42	30.30	31.21
30	*AD Labor Costs*	($000)	199	205	212	218	224	231	238	245	253	260	268	276	284	293	302	311	320	330	339	350
	Engine Plant O&M																					
31	Engine Plant O&M Basis	(MWh)	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180	8,180
32	O&M Cost Rate [1]	(¢/kWh)	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.54	1.58	1.63	1.68	1.73	1.78	1.84	1.89	1.95	2.01	2.07	2.13	2.19
33	*Engine Plant O&M*	($000)	102	105	108	112	115	119	122	126	130	133	137	142	146	150	155	159	164	169	174	179
	Digester Plant O&M																					
34	Digester Plant O&M Basis	($000)	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999	9,999
35	O&M Cost Rate	(%)	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%
36	*Digester Plant O&M*	($000)	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
37	**Utilities, Insurance & Prof Services**	**($000)**	**50**	**52**	**53**	**55**	**56**	**58**	**60**	**61**	**63**	**65**	**67**	**69**	**71**	**73**	**76**	**78**	**80**	**83**	**85**	**88**
38	Contingency Factor [10]	($000)	63	65	66	68	69	71	73	74	76	78	80	82	84	86	89	91	94	96	99	102
39	*Net Expenses*	($000)	697	712	728	745	762	780	799	818	838	859	880	903	926	951	976	1,002	1,030	1,058	1,088	1,118
40	PV Net Expenses	($000)	697	678	661	644	627	611	596	581	567	554	541	528	516	504	493	482	472	462	452	443
41	PV Net Expenses + Capital Costs	($000)	1,726	1,658	1,594	1,532	1,473	1,417	1,364	1,312	1,264	1,217	1,172	1,129	1,089	1,050	1,013	977	943	910	879	850
42	Operating Costs	($/ton)	10.11	10.03	9.96	9.89	9.82	9.76	9.70	9.64	9.59	9.55	9.50	9.46	9.42	9.39	9.36	9.33	9.30	9.28	9.26	9.25
43	PV Operating Costs	($/ton)	10.11	9.55	9.03	8.54	8.08	7.65	7.24	6.85	6.49	6.15	5.83	5.53	5.25	4.98	4.73	4.49	4.26	4.05	3.85	3.66
44	PV Life Cycle Operating Costs	($/ton)	5.62																			
45	PV Life Cycle Op Costs + Cap Costs	($/ton)	12.42																			
46	Net Revenues (Expenses)	($000)	578	607	637	668	700	733	768	804	842	881	921	963	1,007	1,052	1,099	1,148	1,199	1,252	1,307	1,364
47	Present Value of Net Rev (Exp)	($000)	578	578	578	577	576	575	573	571	570	568	565	563	561	558	555	552	549	546	543	540
48	Cummulative PV	($000)	578	1,156	1,734	2,311	2,886	3,461	4,034	4,605	5,175	5,743	6,308	6,871	7,432	7,990	8,545	9,097	9,647	10,193	10,736	11,276
49	Total Cumulative PV of Net Rev	($000)	11,276																			
50	PV of Project Capital Costs	($000)	12,822																			
51	PV of Project Debt Costs	($000)	641																			
52	Net Gain (Loss)	($000)	(2,187)																			
53		($/ton)	(1.11)																			

	Annual Escalation Assumption		
[1]	Annual Inflation	(%)	3.0%
[2]	Present Value Rate	(%)	5.0%
[3]	Waste Flow Escalation	(%)	3.0%
[4]	Energy Price Escalation	(%)	1.0%
[5]	Natural Gas Price Escalation	(%)	1.0%
[6]	Sludges Tip Fee Escalation	(%)	1.0%
[7]	Organics Tip Fee Escalation	(%)	1.0%
[8]	Food Waste Tip Fee Escalation	(%)	1.0%
[9]	Yard Waste Tip Fee Escalation	(%)	1.0%

Bluestem Solid Waste Agency

Mid-Sized AD Expected Present Value Analysis

			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
	Revenues																					
1	Electric Energy																					
2	Net kWh Available for Sale	(MWh)	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393	4,393
3	Energy Price [4]	(¢/kWh)	3.10	3.13	3.16	3.19	3.23	3.26	3.29	3.32	3.36	3.39	3.42	3.46	3.49	3.53	3.56	3.60	3.63	3.67	3.71	3.75
4	***Energy Revenues***	***($000)***	***136***	***138***	***139***	***140***	***142***	***143***	***145***	***146***	***147***	***149***	***150***	***152***	***153***	***155***	***157***	***158***	***160***	***161***	***163***	***165***
	Thermal Energy																					
5	Net Thermal Recovered [3]	(MMBtu)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Natural Gas Price [5]	($/MMBtu)	6.00	6.06	6.12	6.18	6.24	6.31	6.37	6.43	6.50	6.56	6.63	6.69	6.76	6.83	6.90	6.97	7.04	7.11	7.18	7.25
7	***Thermal Energy Revenues***	***($000)***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sludges Tip Fees																					
8	Sludges Per year [3]	(Tons)	16,182	16,667	17,167	17,683	18,213	18,759	19,322	19,902	20,499	21,114	21,747	22,400	23,072	23,764	24,477	25,211	25,967	26,746	27,549	28,375
9	Sludges Tip Fee [6]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
10	***Sludges Revenues***	***($000)***	***243***	***253***	***263***	***273***	***284***	***296***	***308***	***320***	***333***	***346***	***360***	***375***	***390***	***406***	***422***	***439***	***457***	***475***	***494***	***514***
	Other Organics Tip Fees																					
11	Organics [3]	(Tons)	16,650	17,150	17,664	18,194	18,740	19,302	19,881	20,477	21,092	21,724	22,376	23,047	23,739	24,451	25,185	25,940	26,718	27,520	28,346	29,196
12	Organics Tip Fee [7]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
13	***Organics Revenues***	***($000)***	***250***	***260***	***270***	***281***	***293***	***304***	***317***	***329***	***343***	***356***	***371***	***386***	***401***	***417***	***434***	***452***	***470***	***489***	***509***	***529***
	Food Waste Tip Fees																					
14	Food Waste [3]	(Tons)	2,934	3,022	3,113	3,206	3,302	3,401	3,503	3,608	3,717	3,828	3,943	4,061	4,183	4,309	4,438	4,571	4,708	4,849	4,995	5,145
15	Food Waste Tip Fee [8]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
16	***Food Waste Revenues***	***($000)***	***44***	***46***	***48***	***50***	***52***	***54***	***56***	***58***	***60***	***63***	***65***	***68***	***71***	***74***	***77***	***80***	***83***	***86***	***90***	***93***
	Yard Waste Tip Fees																					
17	Yard Waste [3]	(Tons)	362	373	384	396	407	420	432	445	459	472	486	501	516	532	548	564	581	598	616	635
18	Yard Waste Tip Fee [9]	($/Ton)	15.00	15.15	15.30	15.45	15.61	15.77	15.92	16.08	16.24	16.41	16.57	16.74	16.90	17.07	17.24	17.41	17.59	17.76	17.94	18.12
19	***Yard Waste Revenues***	***($000)***	***5***	***6***	***6***	***6***	***6***	***7***	***7***	***7***	***7***	***8***	***8***	***8***	***9***	***9***	***9***	***10***	***10***	***11***	***11***	***12***
20	***Total Revenues***	***($000)***	***678***	***701***	***725***	***750***	***776***	***803***	***831***	***861***	***891***	***922***	***955***	***989***	***1,024***	***1,061***	***1,099***	***1,138***	***1,179***	***1,222***	***1,266***	***1,313***
21	PV Total Revenues	***($000)***	678	668	658	648	639	629	620	612	603	594	586	578	570	563	555	548	540	533	526	519
	Expenses																					
	Fiber Hauling Costs																					
22	Fiber [3]	(Tons)	8,714	8,975	9,245	9,522	9,808	10,102	10,405	10,717	11,039	11,370	11,711	12,062	12,424	12,797	13,181	13,576	13,983	14,403	14,835	15,280
23	Fiber Hauling Cost Rate [1]	($/Ton)	3.00	3.09	3.18	3.28	3.38	3.48	3.58	3.69	3.80	3.91	4.03	4.15	4.28	4.41	4.54	4.67	4.81	4.96	5.11	5.26
24	***Fiber Hauling Costs***	***($000)***	***26***	***28***	***29***	***31***	***33***	***35***	***37***	***40***	***42***	***45***	***47***	***50***	***53***	***56***	***60***	***63***	***67***	***71***	***76***	***80***
	Filtrate Pumping and Treatment Costs																					
25	Gallons of Filtrate [3]	(h Gal)	59,147	60,921	62,749	64,631	66,570	68,567	70,624	72,743	74,925	77,173	79,488	81,873	84,329	86,859	89,465	92,149	94,913	97,760	100,693	103,714
26	Filtrate Pumping Cost Rate [1]	($/h Gal)	0.075	0.077	0.080	0.082	0.084	0.087	0.090	0.092	0.095	0.098	0.101	0.104	0.107	0.110	0.113	0.117	0.120	0.124	0.128	0.132
27	***Filtrate Pumping Costs***	***($000)***	***4***	***5***	***5***	***5***	***6***	***6***	***6***	***7***	***7***	***8***	***8***	***8***	***9***	***10***	***10***	***11***	***11***	***12***	***13***	***14***
	AD Unit Labor																					
28	Annual AD Unit hours	(Hrs)	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720
29	Average AD Labor Rate [1]	($/Hr)	19.00	19.57	20.16	20.76	21.38	22.03	22.69	23.37	24.07	24.79	25.53	26.30	27.09	27.90	28.74	29.60	30.49	31.40	32.35	33.32
30	***AD Labor Costs***	***($000)***	***128***	***132***	***135***	***140***	***144***	***148***	***152***	***157***	***162***	***167***	***172***	***177***	***182***	***188***	***193***	***199***	***205***	***211***	***217***	***224***
	Engine Plant O&M																					
31	Engine Plant O&M Basis	(MWh)	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552	4,552
32	O&M Cost Rate [1]	(¢/kWh)	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.54	1.58	1.63	1.68	1.73	1.78	1.84	1.89	1.95	2.01	2.07	2.13	2.19
33	***Engine Plant O&M***	***($000)***	***57***	***59***	***60***	***62***	***64***	***66***	***68***	***70***	***72***	***74***	***76***	***79***	***81***	***84***	***86***	***89***	***91***	***94***	***97***	***100***
	Digester Plant O&M																					
34	Digester Plant O&M Basis	($000)	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491	5,491
35	O&M Cost Rate	(%)	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%	2.25%
36	***Digester Plant O&M***	***($000)***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***	***124***
37	**Utilities, Insurance & Prof Services**	***($000)***	**38**	**39**	**40**	**41**	**42**	**43**	**45**	**46**	**48**	**49**	**50**	**52**	**53**	**55**	**57**	**58**	**60**	**62**	**64**	**66**
38	Contingency Factor [10]	($000)	38	38	39	40	41	42	43	44	45	47	48	49	50	52	53	54	56	57	59	61
39	***Net Expenses***	***($000)***	***414***	***423***	***433***	***443***	***453***	***464***	***476***	***487***	***499***	***512***	***525***	***539***	***553***	***567***	***582***	***598***	***615***	***632***	***649***	***668***
40	PV Net Expenses	($000)	414	403	393	383	373	364	355	346	338	330	322	315	308	301	294	288	282	276	270	264
41	PV Net Expenses + Capital Costs	($000)	1,138	1,093	1,049	1,008	969	931	895	861	828	797	767	738	711	685	660	636	613	591	571	551
42	Operating Costs	($/ton)	11.45	11.37	11.30	11.22	11.15	11.09	11.02	10.97	10.91	10.86	10.81	10.77	10.73	10.69	10.66	10.63	10.60	10.58	10.56	10.54
43	PV Operating Costs	($/ton)	11.45	10.83	10.25	9.69	9.17	8.69	8.23	7.79	7.38	7.00	6.64	6.30	5.97	5.67	5.38	5.11	4.86	4.61	4.39	4.17
44	PV Life Cycle Operating Costs	($/ton)	6.39																			
45	PV Life Cycle Op Costs + Cap Costs		15.53																			
46	Net Revenues (Expenses)	($000)	264	278	292	307	323	339	356	373	391	410	430	450	472	494	516	540	565	591	617	645
47	Present Value of Net Rev (Exp)	($000)	264	265	265	266	266	266	266	265	265	265	264	263	263	262	261	260	259	258	256	255
48	Cummulative PV	($000)	264	529	794	1,060	1,326	1,591	1,857	2,122	2,387	2,652	2,916	3,179	3,442	3,703	3,964	4,224	4,483	4,740	4,997	5,252
49	Total Cumulative PV of Net Rev	($000)	5,252																			
50	PV of Project Capital Costs	($000)	9,024																			
51	PV of Project Debt Costs	($000)	451																			
52	Net Gain (Loss)	($000)	(4,223)																			
53		($/ton)	(4.08)																			

Annual Escalation Assumptions

[1]	Annual Inflation	(%)	3.0%
[2]	Present Value Rate	(%)	5.0%
[3]	Waste Flow Escalation	(%)	3.0%
[4]	Energy Price Escalation	(%)	1.0%
[5]	Natural Gas Price Escalation	(%)	1.0%
[6]	Sludges Tip Fee Escalation	(%)	1.0%
[7]	Organics Tip Fee Escalation	(%)	1.0%
[8]	Food Waste Tip Fee Escalation	(%)	1.0%
[9]	Yard Waste Tip Fee Escalation	(%)	1.0%